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GRUAN ICM-7 Report

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2. Opening session and keynotes

2.1 Opening notes – Peter Thorne and Greg Bodeker

The GRUAN Working Group co-chairs opened the meeting by welcoming the participants. They thanked Holger Vömel for his contributions as head of the Lead Centre since inception and wished him well in his new position in Boulder. They noted that the meeting focus was on a review of new or under-developed data streams. Fabio Madonna welcomed all participants on behalf of the local hosts.

2.2 GRUAN basics – Ruud Dirksen

After starting with a recap of GRUAN's purpose, goals and modus operandi for new participants in GRUAN, Ruud showed an example of how in the IPCC 5th assessment report, inadequate quality and quantity of water vapour measurements in the UT/LS compromised the determination of water vapour trends in the region and the resultant water vapour radiative forcing. This example, together with a plot showing discontinuities in the 8 km altitude water vapour measurements at Lindenberg, provided further justification of the need for GRUAN.

At the time of ICM-7, five GRUAN sites had been certified. Ruud highlighted the continued need for additional sites in South America and mainland Africa, and welcomed La Réunion as the first GRUAN site in Africa.

Management of change in GRUAN is essential and Ruud's presentation reminded participants of the need for any new measurement system to be thoroughly evaluated prior to implementation. Further work is required by the Working Group to determine suitable periods of measurement overlap to validate the systematic and random errors associated with a new measurement system.

In answer to the question of what constitutes an 'accepted standard' when it comes to ensuring traceability of GRUAN measurements, Ruud explained that if traceability to an SI standard is not feasible, then being traceable to any other internationally recognised standard would be acceptable.

2.3 GRUAN, CNR and Italian Met Service activities – Massimo Ferri

Colonel Massimo Ferri welcomed participants on behalf of the Italian Met Service on behalf of the Italian Permanent Representative to WMO. He went on to provide an overview of operational meteorology in Italy. There are about 170 surface hourly synoptic stations active in Italy. There are also several rainfall radars operated by the Italian Met Service and partners that provide national coverage. Eight upper-air sounding sites are in routine operation; six operated by the Italian Met Service (launching radiosondes twice daily following European observation programme requirements (EUMETNET); RS41 radiosondes are being used), and two by regional agencies. The Met Service sites launch twice daily. One of the sites is a GUAN site. Italy is initiating a national climate service - the National Climate Service Network of Italy (NCSNI) – to connect Italian climate services to WMO climate services. NCSNI will coordinate various services in support of the Global Framework for Climate Services that will include climate monitoring, assessment of trends and changes in variability, seasonal forecasting, and long-term projections for adaptation and mitigation strategies.

Colonel Ferri highlighted national efforts to combine several agencies and research groups to create a larger Met Service than the current Air Force Met Service. There are a number of initiatives to ensure stronger collaboration between agencies in Italy contributing to the provision of meteorological services. There could be an opportunity to rationalise and improve infrastructure and improve Italian meteorology. Fabio Madonna made a comment that there had been discussion regarding relocating a radiosonde observation site as part of this network reorganisation. Greg Bodeker expressed his confidence in the way that the Italian Met Service was working with CNR to improve the operational and research components of GRUAN.

2.4 GRUAN oral history project – Dian Seidel and Ruud Dirksen

Dian and Ruud reviewed the purpose of the GRUAN oral history project i.e. to provide an oral history of the path that has led to GRUAN's success (or not) that is more contemporaneous. The project consists of structured interviews with selected GRUAN participants, following standard practises from historians of science. The ICMs are being used as a venue for these interviews, starting with those who have participated in the establishment of GRUAN, but eventually extending to all involved including adding people from GRUAN's parent organisations. The topics covered in the interviews include information on involvement, recollection of early efforts/challenges, personal memories/anecdotes, the future of GRUAN, and other topics. Dian and Ruud asked for feedback on the idea of the oral history project including how, when, and where to conduct interviews; archive at Lead Centre; volunteers to help; any other ideas. Interview material will be archived at the Lead Centre but will not be made public at this stage. While video recording had at one stage been considered, the decision was made to restrict the interviews to audio recordings only. Photographs are taken however. Videos of GRUAN activities would be a welcome addition to the oral history project and video material being collected in support of the GRUAN promotional video will provide a good starting point. Dian and Ruud will also be looking into including different languages in the responses.

3. Review of progress in the past year

3.1 Lead Centre progress report – Ruud Dirksen and Michael Sommer

Ruud and Michael began by summarizing progress to date on site assessment and certification. In addition to Ny Ålesund and Lindenberg which had been certified in the previous year, this year prior to ICM-7 saw Boulder, Lauder and Payerne certified with Beltsville, Cabauw, Potenza and Sodankylä in the process of being reviewed. Radiosonde data streams for Beltsville and Payerne had been established. While the operation of Darwin as a GRUAN site under the management of ARM had been discontinued (in addition to Manus), it was reported that there were continuing discussions with the Bureau of Meteorology of Australia to continue the operation of Darwin as a GRUAN site. The Lead Centre also reported that Paris and La Réunion had indicated their intention to join GRUAN.

It was reported that Holger Vömel had resigned as Head of the Lead Centre to take up a position at NCAR and that recruitment of a Head for the Lead Centre was underway. As a result of these changes in personnel, fewer resources had been available at the Lead Centre to pursue GRUAN activities.

The Lead Centre has been cooperating with radiosonde manufacturers to use the test facilities available at Lindenberg to test various aspects of radiosonde technology. Both Meisei and Modem participated in the testing of the standard humidity chamber and time lag corrections; the climate chamber at Lindenberg can cool to -80°C and can switch between moist and dry air to test the time response. Pressure dependence of the time lag, while potentially important at low pressures, has not been tested yet. Ruud gave some examples of the outcomes of the testing of the Modem M10 radiosonde. Meisei had also participated in determining radiation corrections. Vaisala participated in software testing and characterisation of the RS41 radiosonde.

The Lead Centre also reported on their cooperation with La Réunion where CFH sondes will be launched from La Réunion as part of the pre-MORGANE campaign.

The Lead Centre has obtained a DOI (Digital Object Identifier) for GRUAN data sets i.e. 10.5676/GRUAN/RS92-GDP.2 which can be appended with a site specific suffix.

Current foci for the Lead Centre are on the development of new data products including the version 3 Vaisala radiosonde data product, data products for Meisei, Meteolabor and Modem radiosondes, a frost-point hygrometer data product, a GNSS water vapour data product, and a Raman lidar data product.

3.2 Assessment of progress against ICM-6 report action plan – Peter Thorne

Participants reviewed progress against the agreed work plan arising from ICM-6. The status of all action items was reviewed as detailed in appendix B. Participants were also reminded of the plans as envisaged in the GRUAN Implementation Plan for 2013-2017 (see GCOS-165). Participants were canvassed on whether the Implementation Plan as it stood was still useful or whether a revision was now warranted that reflected the present day reality as well as new programmatic efforts such as GAIA-CLIM and Meteomet2 which may provide funded effort to advance at least subsets of GRUAN's aims. Specific decisions made following discussion of the achievements on the ICM-6 action plan were:

- To have a generic radiosonde Technical Document (omnibus) with specific annexes relevant to each radiosonde type.
- To have a paper submitted for publication in the international peer reviewed literature before the end of 2015 that summarizes the difference in performance of radiosondes launched manually or by an autosonde launcher.
- To advance the development of microwave radiometer and FTIR GRUAN data products through the GAIA-CLIM European project.
- To remove the immediate specific action requiring extension of GRUAN data products to other ECVs, but to retain this as a long-term goal for the network.
- To revise the GRUAN Implementation Plan to better reflect the current status and funded efforts within GRUAN. The revised Implementation Plan will be co-owned by the Working Group and the Lead Centre and will be written at a more programmatic level rather than being overly specific.

3.3 Progress report from the Radiosondes Task Team – Masatomo Fujiwara

The Task Team on radiosondes now comprises 14 members including three new members. Achievements across four main tasks, viz.

1. RS92 relative humidity time lag corrections: An intercomparison of GRUAN and other (e.g. Miloshevich) RS92 relative humidity time lag corrections has been performed. Preliminary results were presented and discussed.
2. Manual vs. autosonde launchers: Data from Sodankylä, Tateno and Potenza are being analysed to assess effects on measurement uncertainty estimates. The French group are also considering using an autosonde launcher.
3. Controlled descent assessment: Researchers from Boulder, Lauder, Payerne and Lindenberg are involved. The goal is to assess controlled descent mechanisms for balloon payloads and whether there are likely to be any problems with the use of data measured on descent. The radiosonde Technical Document omnibus is expected to include a section that discusses controlled descent mechanisms and the use of measurements obtained on descent. Ideally it would also be published in the literature.
4. Multi-payload launch configurations. The goal of this task is to assess multi-payload launch configurations for use in GRUAN. A draft manuscript is being prepared that describes the advantages and disadvantages of various configurations. It was not clear whether a single recommendation could be made. It was decided that this material would be suitable for publication as a journal paper (e.g. in AMT) with subsequent inclusion in summary form in the GRUAN radiosonde Technical Document.

Achievements across four secondary tasks, viz.

1. Non-RS92 radiosondes: Data collection client requirements are being defined for Meteolabor, Modem, and Meisei radiosondes. Annexes to the radiosonde Technical Document, describing the data processing characteristics unique to these radiosondes, are being written. Next steps are to identify a central GRUAN data processing facility and initiate data flow.
2. Water-vapour sondes: Technical documents and data collection client requirements for frostpoint hygrometers (CFH, FPH, Snow White) and other hygrometers (e.g., FLASH-B) are to be developed.
3. GRUAN Data Product for RS92: The Task Team is assisting the Lead Centre with finalizing the definition of the data product.
4. The Task Team will support the writing of the GRUAN ozonesonde Technical Document.

The Task Team should inform CIMO when new information and papers regarding radiosonde operation become available so that this knowledge and expertise can be disseminated across the regular radiosonde network. Task Team members committed to participating in future updates to the CIMO Guide if requested to do so..

3.4 Progress report from the GNSS-PW Task Team – June Wang

The Task Team comprises 10 members from 7 countries. June began by reminding the participants that the goal of this Task Team is to develop explicit guidance on hardware, software and data management practices to obtain GNSS-PW measurements of consistent quality at all GRUAN sites. June showed results from GNSS-PW measurements at Ny Ålesund where automated, robust continuous measurements of the total water vapour column are particularly useful. Measurements from 1999 to 2015 show that long-term, seasonal, and synoptic variability is well captured by 2-hourly data. Specific areas where this Task Team has made progress over the past year include:

- Updating the terms of reference i.e. moving beyond defining the GNSS-PW data product to updating the definition and implementing the data flow.
- GNSS-PW uncertainty estimate paper: a draft manuscript has been completed and is planned for submission by September 2015.
- The writing of a Technical Document omnibus for GNSS-PW is proceeding.
- GNSS-PW data flow and processing: Data processing for GRUAN is being developed by GFZ.

Future work will include:

- Work with GFZ on implementation of uncertainty estimation methods.
- There is a need to define data requirements and contacts for raw data. There is also a need for a process of assessment of data usage and the reporting of data use issues as this GRUAN data product comes on line.
- Research into new GNSS capability with new satellites. Collaborations are underway with the GNSS4SWEC project.
- There are plans to compare different GNSS antenna systems once the centralized data processing has been implemented. This will facilitate an easy comparison of instrumental differences.

As delivery of the GRUAN GNSS-PW data product is operationalised and becomes routine, this Task Team might go into ‘hibernation’. Remaining research aspects could be picked up by the GRUAN Science Coordinators.

3.5 Progress report from the Scheduling Task Team – Tom Gardiner

Tom began by giving an overview of the objectives of this Task Team. The primary goal of the Task Team is to develop defensible, quantifiable, scientifically-sound guidance for GRUAN sites on measurement schedules and associated site requirements, to meet all GRUAN objectives including climate trend detection, satellite calibration/validation, and studies of local mesoscale processes and events. While the main information sources are from peer-reviewed literature, GRUAN documentation, and currently unpublished studies, the Task Team has also conducted new analyses to fill critical gaps.
Tom updated the meeting attendees on specific achievements of the Task Team in the previous year, viz.:

- A report was published summarising the peer-reviewed literature on sonde temperature measurements scheduling: GRUAN Report no. 3 ‘Review of Operational Requirements for Temperature Sonde Measurements’.
- A paper was published on temporal sampling and diurnal variability in sonde temperature measurements: Butterfield, D. and Gardiner, T., Determining the temporal variability in atmospheric temperature profiles measured using radiosondes and assessment of correction factors for different launch schedules, *Atmos. Meas. Tech.*, 8, 463-470, doi:10.5194/amt-8-463-2015, 2015.
- Dave Whiteman’s paper on lower stratospheric water vapour trends was revised.

Specific conclusions from the report on sampling required for radiosonde temperature measurements include:

- Sampling twice daily at 00:00 and 12:00 UTC ensures that monthly statistics will be statistically significantly different from those based on four observations per day in only ~5% of the cases.
- Sampling once daily introduces biases in monthly mean temperatures.
- Large errors result from changing from 00:00 to 12:00 UTC observations (or vice versa).

- Twice-daily sampling must be done at least once every two days to ensure that monthly means are accurate to within 2 K.
- Sampling every two days, or every three days (but not every seven days), yields monthly means and standard deviations that are not significantly different from the true values at least 99.5% of the time.

Short-timescale sampling challenges include:

- Given the wide potential range of short-timescale applications (for process studies and satellite validation), it is difficult, if not impossible, to prescribe a fixed set of sampling guidelines.
- One option is to estimate the increased uncertainty due to non-simultaneous temperature measurements from satellite and radiosonde. This would enable an appropriate sampling strategy to be put in place for a given requirement/application.
- The Task Team has produced estimates for sonde temperature measurements from actual datasets, as a function of time of day, altitude and season.

To conduct these studies, sites providing at least 4 radiosonde flights per day were needed. These included Manus (which flew 8 flights per day for a 6 month period) and Lindenberg and Southern Great Plains (Lamont) which both flew 4 flights per day. The study considered the ability of various launch schedules to capture diurnal variability; 4 launches per day are usually sufficient. Tom also presented an update on the lower stratosphere water vapour trend study. A paper is under revision for re-submission to Geophysical Research Letters. The main conclusions of the paper are:

- Because the variability of lower stratospheric water vapour is low, a small number of measurements with small random uncertainty, is sufficient to reveal trends.
- Trend detection improves slightly when the number of measurements increases from 1 to 7 per month.
- Because trends as a function of pressure level are highly correlated in 10° zones, it is more important to place new sites in different latitude zones than to duplicate sites in zones already being sampled (e.g. especially in Northern Hemisphere midlatitudes).
- Due to the much higher random noise, Raman lidar is not as attractive as frostpoint hygrometers or the space-based Microwave Limb Sounder for monitoring trends in lower stratospheric water vapour.

There is a need for peer reviewed papers on adaptive measurement scheduling. There was also some discussion about high temporal density (more than 4 flights per day) radiosonde data. Roger Atkinson is to advise the Task Team on data availability – there may have been a campaign with 6 sites around Darwin measuring at high frequency for 2 months. In answer to a question on measurements scheduling for sites that are not launching on a regular schedule, it was clarified that it is not necessary to launch on a regular schedule since NWP centres are moving towards adaptive launch schedules. Furthermore, there are benefits to be had for satellite validation when measurement schedules are not fixed and launch times can be adapted to match satellite overpasses.

3.6 Progress report from the Ancillary Measurements Task Team – Thierry Leblanc

Thierry began by reviewing the Task Team terms of reference. There had been no change in Task Team membership over the previous year. Thierry then proceeded to discuss progress on the development of GRUAN data products for FTIR, lidar, microwave radiometer and AERI. The primary information in Thierry's presentation included:

- The document for best measurement practices and guidelines for lidar within GRUAN is on hold until the GRUAN lidar data stream is fully mature.
- In the previous year no progress has been made on development of the GRUAN LidarRunClient, activity was about to resume with the expectation that the first operational version would be completed by mid-2015.
- Good progress had been made on the GRUAN Lidar Data Stream: Data processing (GLASS). Raw lidar data from three GRUAN sites (Payerne, Potenza, and Ny Ålesund) can now be analyzed, the plan is to extend this to Cabauw and Beltsville in the near future.

- Version 0.8 of the Microwave Radiometer Guidelines was completed prior to ICM-7 with a complete draft expected by June 2015. The microwave radiometer documentation will conform to the standard structure for GRUAN Technical Documents as outlined in GRUAN Technical Note 2.
- Further work is required, in collaboration with Jonathan Gero, to compile an inventory of AERI instruments for consideration by the Task Team and to then report to the GRUAN community on the viability of bringing AERI into GRUAN.

Plans for the coming year include:

- Guidelines and best practices for all ground-based techniques to be completed by mid-2015.
- Lidar data streams for at least three GRUAN sites are expected to become available.

During the subsequent discussion, it was decided that for GRUAN certification of specific measurement programmes, while the GRUAN Working Group co-chairs and Lead Centre would oversee the certification, the relevant Task Team would perform an essential role in assessing the technical details of an application. Technical Documents for any GRUAN data product must therefore define clearly the certification requirements for any measurement programme providing data for that product.

3.7 Progress report from GRUAN Science Coordinators – Tom Gardiner and Richard Querel

Tom and Richard began by providing some background to the establishment of the GRUAN Science Coordinator roles. The main focus to date has been a series of one-to-one discussions to gather individual views on GRUAN and the priorities for scientific coordination which has been summarised in a report. On the basis of the initial feedback, Tom and Richard have reviewed the scope for the Science Coordinator activities and identified a number of scientific areas where cross-network collaboration would be greatly beneficial. The original scope for the role focussed on identifying and coordinating short-term (1-6 month) research projects and outcomes to support GRUAN objectives. While this is still a high priority, it has been extended to include:

- Identifying common areas of scientific activity across GRUAN, and to look at facilitating cooperation and knowledge exchange between the groups involved.
- Defining research topics appropriate for longer term study that could form the basis of future research proposals and identify the potential stakeholders/collaborators for such research.
- Building a database of relevant publications that may be of interest to GRUAN.

The main outcomes of the one-to-one discussions that the Science Coordinators have had to date (12 people spoken to) include:

- GRUAN is both exciting and frustrating; it seems to lose momentum unless exciting things happen.
- There is a need to market the benefits of GRUAN internally and externally through a series of case studies.
- Most sites currently have no funding dedicated to GRUAN; the Science Coordinators will provide ideas and/or a template for how sites could seek funding.
- A data qualification process needs to be defined for new radiosondes coming into GRUAN.
- A roadmap is needed from the Lead Centre as to how sites should switch from RS92 radiosondes to a range of alternatives.
- With regard to data processing and uncertainties there is a need to demonstrate the added value of GRUAN analysis of raw data. There is also a need to standardize uncertainty reporting for various instruments (in-situ vs. remote).
- Regarding NWP and satellite validation, while the use of GRUAN data for satellite validation is often emphasized, it is not clear whether the GRUAN data products are currently being used for this purpose.
- There is a need for better two-way communication between GRUAN sites and "regular" operational sites so that GRUAN can raise the quality of GUAN measurements.

The Science Coordinators have identified four initial areas for coordinated activity, viz.:

1. OSSEs: This connects to recent developments in NOAA. To make progress, this project needs the commitment of an experienced scientist and significant time. It is therefore unlikely to be suitable as a short term project or a PhD project. The primary goal for an OSSE project would be to aid GRUAN network design by answering the question of where new GRUAN sites would add most value. Setting up the OSSE is the main challenge. The goal of the OSSE would need to be clarified and exactly which GRUAN objectives are being addressed. Conducting an OSSE for a climate network is new and has not been done before. This project would therefore lead to ground-breaking science.
2. SASBEs: Development of SASBEs provides good opportunity to demonstrate GRUAN benefits since it links to collocation and measurement redundancy uncertainty work and could provide a rigorous assessment of the uncertainty of the atmospheric state. There are obvious links to the GAIA-CLIM project (see later). The are many additional linked research topics including vertical correlation of uncertainties from different measurement techniques (how to combine and report them) and uncertainty introduced by radiative transfer models when converting between parameter space and radiance space.
3. Sonde qualification: There may be a role for the Science Coordinators to coordinate efforts related to GRUAN qualification for non-RS92 sondes.
4. Data timescales: This was an issue raised by potential NWP users of GRUAN data i.e. the timeline for data availability, and how this links to the timescales for operational inclusion into NWP models. One potential study would be to look at the timescales for the various data streams and the added value (in terms of data quality and traceability) as a function of time/analysis steps. This would assess how and when current data streams could be used in NWP, and provide guidance on the development of new data streams.

Next steps to be undertaken by the coordinators include:

- Identifying interested groups in research areas and help coordinate collaborations.
- Developing a list of smaller research projects under broad themes.
- Developing a database of papers of likely interest to the GRUAN community.

Outcomes from the subsequent discussion included:

- It is important that the GRUAN Science Coordinators connect to groups outside of GRUAN, and to users who are not measurement specialists.
- The GRUAN community feels isolated between ICMs and more needs to be done to maintain momentum between ICMs. This therefore needs to extend beyond the Working Group. The GRUAN blog and wiki will be used in the first instance to maintain the information flow. A quarterly GRUAN newsletter will also be produced to this end.
- The Science Coordinators agreed to alert the GRUAN community to relevant funding calls.

4. Radiosonde data streams

4.1 Development and certification of GRUAN data products – Holger Vömel

Holger began by reminding the participants what distinguishes a GRUAN data product from data products available elsewhere, viz. quantified uncertainties, manufacturer independent ground-checks, documentation, dedicated data flow and certification. Uncertainties in GRUAN data products are determined through laboratory studies, theoretical studies, comparisons of in situ measurements against standards, and through quantified corrections. Certification of GRUAN data products is needed to verify that the process is appropriate, verify that the results meet expectations, identify shortcomings in the data processing chain, and make all steps in the processing transparent.

Outcomes from the subsequent discussion included:

- Whether there is an expectation that all sources of uncertainty in GRUAN data products should be 'split out' i.e. made available to users. It was agreed that while it is essential to have disaggregated measurement uncertainties, it is the net uncertainty that is of most use to the data user. The disaggregation should be available in principle but need not be provided in every data file for every GRUAN data product.
- Certification of GRUAN data products needs to occur before sites are certified to run measurement programmes to provide the data needed to construct those data products. Publication of a paper should be sufficient for data product certification. The metrology community can play a key role in GRUAN data product certification.
- The Lead Centre, relevant task teams, and the Working Group will all take a central role in the certification of GRUAN data products.

4.2 Proposed format for Technical Documents for radiosondes - Michael Sommer

Michael began by pointing out that while we need Technical Documents for all radiosonde types, about 75 % (or more) of the material would be common across all radiosonde types e.g.:

- Recommended pre-launch procedures and launch setups.
- Important sensor characteristics/errors, e.g. time-lag, radiation bias.
- Algorithms to correct data and estimate uncertainties.
- Attributes of the measurement including establishing reference quality measurements, scheduling, and quality control.
- Relevant meta-data and GRUAN data flow (incl. used tools).

But this material need not be repeated across multiple Technical Documents. The proposed solution, therefore, is to provide one Technical Document for all radiosondes, using the structure outlined in GRUAN Technical Note 2, that:

- Describe all aspects of the GRUAN radiosonde operation that is common to all sonde types.
- Indicates where sondes will differ in some particular regard.
- Provides examples of the topic in general but then refers to 'subsidiary' Technical Documents for each radiosonde type that defines their unique characteristics.

Michael provided an overview of the structure of the general Technical Document for radiosondes and the themes that would be covered by the radiosonde-specific subsidiary Technical Documents for each radiosonde. The Lead Centre will initiate the process by assembling a team of three editors from the Lead Centre and the Task Team on radiosondes that will focus on writing the overarching radiosonde Technical Document. They would seek assistance from the GRUAN Document Curator. Additional authors will be brought on-board from the Lead Centre, the Task Team on radiosondes and from elsewhere. The subsidiary Technical Documents will be written by instrument specific teams and will follow a prescribed template that will be provided by the Lead Centre. The goal is to commence the work in April 2015 and to have a version that can be reviewed by ICM-8.

Outcomes from the subsequent discussion included:

- There will be sites in GRUAN that may deviate in some way from the prescribed GRUAN protocol for the operation of radiosondes, perhaps because of site specific environmental conditions, and that information on how and why they deviate from the GRUAN standard needs to be captured somewhere. It was agreed that this should be captured in the general Radiosonde Technical Document.
- It was also suggested that the Technical document writing team should include not only experts, otherwise it becomes too technical. The Technical Documents need to be intelligible to non-experts.

4.3 Version 3 of the GRUAN RS92 radiosonde data product, what is new – Ruud Dirksen

Ruud began by reviewing the heritage of the GRUAN data processor. Version 1 of the processor was designed by Franz Immler and Michael Sommer over the period 2008-2011. While some of the correction algorithms (e.g. time lag, calibration correction) were based on existing literature, others (e.g. the radiation correction) were developed specifically for the GRUAN data processor. The version 1 data processor integrated with the GRUAN metadata base and included vertically resolved measurement uncertainty estimates. The second version of the GRUAN data processor for radiosonde data became available in September 2012 and is documented in Dirksen, R.J.; Sommer, M.; Immler, F.J.; Hurst, D.F.; Kivi, R. and Vömel, H., Reference quality upper-air measurements: GRUAN data processing for the Vaisala RS92 radiosonde, *Atmos. Meas. Tech.*, 7, 4463-4490, 2014. Ruud proceeded with displaying the flow diagram of version 2 of the GRUAN data processor and outlined the motivations for developing a 3rd version of the GRUAN radiosonde data processor, viz. restructuring the program code to make it more modular, enabling the transition to MW41 receiving systems, improving user feedback (e.g. clear message in the case of failed quality control) based on input from the co-chairs of the Sites Task Team, and to make the processor more generic so that it can deal with non-RS92 radiosonde data.

The dataflow for version 3 of the GRUAN data processor will be able to take raw data and metadata from a range of radiosondes (RS92, RS41, DFM09, M10, SRS34, RS-11G, intermet etc.) and will first convert that into a uniform raw data NetCDF file. Correction algorithms coded in a number of modules will then be applied before post-processing, which includes the calculation of measurement uncertainties, and generates the final data product in NetCDF format. Ruud provided some examples of the building blocks for the new version 3 of the data processor. There are choices to be made when applying the radiation correction, and the choice of when to sample the radiation correction curve can have a significant impact on the resultant temperature correction, particularly above 20 km altitude. For version 3, a new radiation correction will be applied and the humidity profile will be scaled with the results from the standard humidity chamber ground-check. It is not known yet whether the radiation correction improves the estimate of the temperature uncertainty.

Outcomes from the subsequent discussion included:

- In response to the request from users of GRUAN data for 'partial profiles', or profiles where not all of the data had passed all tests, to be included in the database, in future all/most profiles that can be processed will be available through the GRUAN data portal with the relevant flags highlighting to the users which data may have failed specific tests. Data that are entirely bad (e.g. resulting from a broken sensor) will be replace by NaN. It will then be left to the user to decide which data are acceptable for their purposes and which are not.
- All existing GRUAN data will be reprocessed through the version 3 GRUAN data processor. People who have registered as users of GRUAN data will be informed when version 3 data are available. Version 2 data will still exist and publications can continue to use that version of the data. The version 3 database will have its own DOI number unique from that for version 2.
- The new radiation correction and its uncertainty will need to be validated. One option is to use the lidar temperature products for the stratospheric validation. Thierry Leblanc is to provide suggestions to the Lead Centre of potential suitable sites.
- More thought needs to be given about justifying when to move from one data version to another. In addition, once GRUAN is providing multiple versions of one data product, we should consider a framework for automatic intercomparison of different versions of a data product e.g. in the form of on-the-fly intercomparison plots.
- It was decided that for version 3 (as was the case for version 2), the data files would provide the correlated and uncorrelated measurement uncertainties, but not every component of the uncertainty.

4.4 Meteolabor sonde: progress, plans and intercomparisons – Rolf Philipona

Rolf began by providing an overview of laboratory and atmosphere experiments to characterise the radiation corrections that need to be applied to the sondes. These experiments included:

- Measurements of the solar radiation effect on unshaded and shaded temperature sensors in flight to determine the contribution of radiation to the temperature measurement uncertainty,
- Measurements of the radiation effect error on temperature sensors in a vacuum chamber in Lindenberg to confirm the results obtained from atmospheric measurements, and
- Measurements of solar and thermal radiation flux profiles through the atmosphere to determine the effect of sensor diameter on the thermal night-time radiation effect on the temperature sensor.

Rolf then went on to show differences in relative humidity between the meteolabor and RS92 radiosondes. Temperature differences between the SRS-C34 and RS92 radiosondes observed during the China intercomparison were confirmed at Payerne. Dual soundings were also performed to test the reproducibility of the results.

Outcomes from the subsequent discussion included:

- Humidity measurements from the current meteolabor sonde are only likely to be good up to 8 km altitude.
- Data from the new meteolabor radiosonde will be submitted to the Lead Centre starting in January 2016 it is hoped that will then have the correct GRUAN ready quality humidity measurements.
- RS41 data from the 3-way launches being conducted at Payerne will be shared with the Lead Centre so that they can investigate RS92/41 differences.
- Meteolabor SRS34 radiosonde data being submitted on the GTS are being labelled as SRS400 data. Tony Reale and Rolf agreed to resolve this.
- Rolf and Ruud Dirksen agreed to examine the temperature differences between the RS92 and meteolabor radiosondes (RS92 appears to be biased cold). It was emphasized that with the version 3 processing of the RS92 data (see above) the resultant temperature corrections will make these differences even larger.
- It needs to be examined whether the RS92 and meteolabor radiosonde temperature profiles agree within their stated uncertainties (e.g. by looking at the data from the 3-way comparisons). If they overlap better than expected then it is possible that the uncertainties are being overestimated and this would need to be looked into. Day-night differences in the temperature differences between RS92 and meteolabor also need to be investigated.

4.5 The Modem sonde data product; progress and plans – Martial Haeffelin

Martial began by reviewing the relative humidity corrections and their uncertainties as determined for the M10 radiosonde. The M10 sonde estimates humidity by using a microcontroller to measuring the oscillation frequency of a capacitive sensor. The ground calibration is achieved by measuring the oscillation frequency at 55% humidity. Corrections that need to be applied include:

- Capacitor frequency varies with temperature.
- There is a temperature difference between the ambient air and the capacitor and since the relative humidity is measured at the capacitor temperature, this introduces a dry bias. The new correction for the M10 sonde now takes into account the mean $T_{air} – T_{capacitor}$ as a function of height and air temperature.
- The time response of the capacitor is temperature dependent – this introduces a ‘fast response’ of the order of seconds. This response has been characterized by matching ascent/descent humidity gradients at the tropopause giving response times of 18s at -40°C, 90s at -60°C, and 280s at -80°C.
- Diffusion of air molecules into the capacitor (which is an issue near 0% and 100% relative humidity) introduces a ‘slow response’ of the order of minutes. The characterisation of this correction is still a work in progress.

Martial went on to show some results from tests and intercomparisons of the M10 radiosonde humidity sensor with other sondes at Lindenberg, Payerne and Paris. He also showed some preliminary results of the humidity sensor uncertainty derivation. The two main sources of M10 humidity uncertainty are uncertainty in capacitive sensor temperature (dry bias) and uncertainty in the time constant (time lag). Calibration uncertainties are yet to be accounted for. Badosa et al. are preparing a manuscript for publication in *Atmospheric Measurement Techniques* that discusses the M10 relative humidity measurements, corrections and uncertainties.

M10 temperature measurements are made using a low tolerance thermistor calibrated at room temperature together with a standard calibration curve. The electronic circuitry manages changes in sensor sensitivity over three dynamic ranges. Radiation corrections that need to be made include an actinic radiation flux correction, a convective cooling correction that depends on atmospheric pressure and wind speed, and a correction to account for conduction of heat through the wires. Either a linear or power dependence can be assumed for these corrections. The behaviour of the M10 sonde has been tested in the DWD vacuum radiation chamber. The results of the temperature correction tests were also shown.

The ground-check corrections for the M10 sonde to meet GRUAN requirements for reference measurements were also presented. This is a two-step procedure that takes about 10 minutes per sonde. The ground-check includes a 100% relative humidity check. The use of robotsonde operations was also presented. As far as Martial is aware there have been no studies on the reliability of the M10 robotsonde. Martial presented the GRUAN M10 data processing and documentation. The finalization of the M10 GRUAN data product will happen in 2015 and GRUAN certification of the M10 product will happen in 2016.

Martial finished his presentation by showing a map of where M10 sondes are used. More than 40,000 radiosonde profiles are measured each year using M10 radiosondes.

Outcomes from the subsequent discussion included:

- It was suggested that it would be good for all of the people who are working on radiosonde uncertainties to get together to discuss how best to do that. A suggestion was made that perhaps a Task Team should be established to ensure that best practice was always being followed in determining measurement uncertainties and that best practice was being shared between groups. Martial responded by saying that a Task Team on uncertainties would be a good idea and that holding a workshop on uncertainty estimates would also be a good idea.
- The question was raised regarding whether all sites using M10 sondes had updated from the M2K2 sonde and whether intercomparisons had been done between the M10 and M2K2 sonde as this would be useful to GRUAN. MeteoFrance has done this and some data sets are available.
- Given the large number of stations flying M10 sondes, the question was raised as to whether other M10 sites could be encouraged to join GRUAN. Martial replied that if a meteorological service or research centre who would be willing to do the extra work could be identified, MeteoFrance could help with the data processing. Greg agreed to follow-up with Martial on options to explore.
- It was pointed out that there were many sites on Martial's M10 map that were not reporting data on the GTS. Martial replied that the Argentinian network is in the process of being set up and is not yet operational. Martial will update the M10 map.
- It was pointed out that the M2K2 and M10 sondes have large uncertainty in temperature when the radiosonde emerges from cloud; has any work been done with Modem to address this? Martial replied that work has been done and that differences from other instruments have been much reduced after these effects have been accounted for in the processing.

4.6 Managing the transition from RS92 to RS41 discussion – Ruud Dirksen lead discussant

Production of Vaisala RS92 radiosondes will be phased out in the next 3 years. The intention of Vaisala to produce the RS41 sonde was officially announced in 2013. Ruud gave a description of the key differences between the RS92 and RS41 radiosondes. While there have already been a number of RS92/RS41 intercomparison campaigns, and more are expected in the future, there is a need for coordinated GRUAN-wide management of this change; there are 13 sites in GRUAN currently flying RS92 radiosondes. An intercomparison of 19 dual night-time RS92/RS41 flights at Table Mountain facility (not a GRUAN site at this time) showed RS41-RS92 temperatures differences being ~0.07°C around 7 km altitude with smaller differences above and below. The RS41 tends to show relative humidities >10% higher than RS92 above around 17 km. Results from intercomparison campaigns need to be synthesized across GRUAN. Because several of these sites are considering switching to RS41, it is realistic to consider the switch from RS92 to RS41 as an example of the change management required, whilst being cognizant that this does not constitute the only possible pathway sites may choose.

Transition from RS92 to RS41 (or any other sonde sites choose) constitutes a new GRUAN data product and/or change management. This will require a new determination of uncertainties through laboratory measurements and sonde intercomparisons. Laboratory tests of the RS41 radiosonde have already been performed at Lindenberg including calibration (standard humidity chamber with reference saline solutions), time lag correction using the climate chamber, and radiation corrections needed for the temperature sensor. It was found that at 300 hPa the radiation correction for the temperature sensor between RS92 and RS41 sondes is about the same. However, at pressures below 30 hPa, the radiation correction for the RS41 sonde is smaller than for the RS92 sonde because the RS41 reaches an equilibrium temperature faster than the RS92 sonde.

The plan proposed by the Lead Centre for network-wide coordination of the transition from RS92 to RS41 (or other) radiosondes is that selected sites in the network, representative of large climatic zones, fly dual RS92/RS41/other flights weekly for a period of one to two years. Other sites in the same zone conduct dual soundings for short periods four times each year (to capture any seasonal dependence) for two years. It was recognized that parallel soundings incur an additional financial burden and could require additional ground-station hardware (which could be leased). The Lead Centre can provide one MW41 station for up to one year as well as additional radiosondes.

Outcomes from the subsequent discussion included:

- The idea of interlacing radiosonde flights (switching between different sonde types on alternating days) and using a statistical regression model to diagnose the systematic biases between the two sonde types was raised. It was recognized that the utility of this method would need to be proven before it could be adopted by GRUAN.
- The discussion clarified that GRUAN was not advocating for a shift from RS92 to RS41 radiosondes but a shift from RS92 to a range of other radiosonde types.
- It was pointed out that radiosonde type differences can show significant site dependence and it would not be appropriate to rely on a few sites only to diagnose the differences between RS92 and replacement radiosonde types.
- GRUAN should use the RS41SGP radiosondes that still include a pressure sensor; the standard RS41 radiosonde uses only GPS for altitude and does not include a pressure sensor. This was deemed not to be desirable for GRUAN.

4.7 The Meisei sonde data product; progress and plans – Nobuhiko Kizu

Kizu-san began with an overview of the RS-11G and iMS-100 Meisei radiosondes. For JMA (Japan Meteorological Agency) a key consideration in their choice of radiosonde is safety. For this reason their requirements are for a sonde weighing 180g or less, with a terminal velocity of $12 m.s^{-1}$ or less, a non-rigid plastic housing, an impact force of 850 N or less, and a string no longer than 10 m. To accommodate these requirements, they are willing to accept a radiosonde volume of up to 1000 cm^3. Both the RS-11g and iMS-100 sondes meet these requirements. The performance of the Meisei radiosonde hardware was compared with the RS92-SGP hardware which is what had previously been used by JMA.

Kizu-san then went on to outline the Technical Note that would describe the GRUAN data product for the Meisei radiosonde. Corrections applied to the temperature measurement were presented, and in particular the source of, and correction for, heat spikes in the temperature measurement. The required radiation corrections were also described in detail. These radiation corrections were verified through experiments conducted at Lindenberg. The uncertainty in the radiation correction to the temperature measurements which arises primarily from uncertainty in the flux of radiation incident on the sensor, and the uncertainty in the wind speed measurement, was also discussed

The humidity data processing chain for Meisei radiosondes was also presented. This includes corrections resulting from the standard humidity chamber pre-flight ground-check and humidity sensor time-lag correction. Standard humidity chamber-based corrections include 6 manufacturer calibration points plus the 0% and 100% calibration points by JMA to give a total of 8 calibration points. Corrections are also made for moist air contamination that occurs after the sonde passes through cloud or rain, and for temperature dependence of the performance of the humidity sensor. The uncertainty budget resulting from known sources of uncertainty, and from the application of these corrections, was summarized.

Comparisons of the RS-11g and RS92 radiosonde performance were presented, including differences between raw and corrected RS-11g data. Timelines for transitioning from RS92 to RS-11g, for the writing of the GRUAN Technical Document for Meisei radiosondes, and for the development of the Meisei GRUAN data product were also presented. The presentation finished with a discussion of plans for the future.

Outcomes from the subsequent discussion included:

- Whether pre-flight humidity sensor calibrations should include points other than just at 0% humidity and at 100% humidity.
- Since a 10 m unwinder results in an increase in spikes on the radiosonde temperature measurement, it was questioned whether a longer unwinder would be advisable. The answer was that a short unwinder is mandatory since if any longer it results in a greater chance for interference with powerlines on landing.
- In addition to the Meisei radiosonde being described in a GRUAN Technical Document, it will also be described in a peer reviewed publication.

4.8 The CFH data product progress – Holger Vömel

Holger began by reviewing the CFH uncertainty budget which is disaggregated into:

- Thermistor calibration which is <0.05 K (<1% mixing ratio), is systematic throughout the profile, and systematic in time.
- Manufacturing variability which is <0.2 K (<4% mixing ratio), is systematic throughout the profile and random in time.
- Controller stability which is between 0.1 K and 0.5 K (2% to 10% mixing ratio), is random throughout the profile and random in time
- Proportional–integral–derivative (PID) controller drift which is 0 K systematic throughout the profile, and random in time series.

In addition, contamination from e.g. the balloon can be large and is flagged out during post-flight processing.

Holger went on to show some results of CFH intercomparisons at Lindenberg. A paper describing the CFH GRUAN data product is in preparation. Smoothing and averaging is done to provide mean, standard deviation and time resolution profiles for each sounding. Vertical profiles of raw and smoothed data, and time resolution are provided in the data product. Ground-checks of the frost point temperature against a polymer measurement show differences typically less than 0.1°C. Regarding data flow, Holger pointed out that the data are not yet publicly available since the description of the GRUAN data product is not yet complete. It is also necessary to develop processes to merge the CFH data stream with the radiosonde humidity sensor data stream so that a single vertical water vapour profiles results. The centralised data processing facility for CFH sondes will be NCAR. It was suggested that certification of the CFH data stream should be done by the Radiosonde Task Team followed by submission of a peer-reviewed publication.

Outcomes from the subsequent discussion included:

- The question was raised as to which variable does the uncertainty relate to? The answer was frost point. It is easy to convert this to uncertainty on other water vapour variables using equations that will be provided.
- The need for a Technical Document describing the CFH GRUAN data product was raised. While Holger felt that a Technical Document was not necessary, the ARM sites require a Technical Document to meet ARM's need for strict, detailed instrument handbooks. Other sites will also require step-by-step instructions for CFH operation.
- It was reiterated that ground-checks for CFH flights are required. The ground-check is not used to correct the data, it is just used for performance checking; therefore there is no need to stop data processing if no ground-check is available.
- Sites that have a capability of measuring the troposphere-stratosphere water vapour profile using means other than CFH should also be considered.
- The process of merging CFH water vapour profiles with radiosonde humidity profiles, including non-RS92 radiosondes, was also discussed.

The CFH discussion was followed by a more general discussion on sonde programmes in GRUAN. Specific points covered in that discussion included:

- The need for another WMO/GRUAN radiosonde intercomparison that would compare and test radiosondes with all corrections and uncertainty estimates in a field campaign. If GRUAN ground-check and other procedures were applied in such an intercomparison, it would provide a further interaction point between the GRUAN and GUAN communities.
- There is value to be had in processing radiosonde data from non-GRUAN sites through the GRUAN radiosonde data processor. There is a need for the Lead Centre to provide a radiosonde data processing package that can be used for on-site near-real-time data processing that is different from the manufacturer data processing.

5. Homogeneity and metadata

5.1 What about cross-network homogeneity? – Michael Sommer /Ruud Dirksen

This presentation aimed to highlight issues related to ensuring network wide homogeneity. Changes that take place at a site can be either controlled changes e.g. a change in instrumentation, a change of operators, or optimisation of operational procedures, or can happen as an uncontrolled change e.g. when a manufacturer makes an undocumented change in the manufacturing process to 'optimize' the performance of the instrument e.g. a change in sonde processing batch. There are also many sources of inhomogeneity resulting from differences across the network. Such inhomogeneities can be caused by site-to-site differences in operational procedures (e.g. the use of a standard humidity chamber for ground-checks), location (e.g. sea-level/mountain differences), the instrument used to make the measurement, the version and configuration of software systems used to process the raw measurement data, and change management. Inhomogeneities at any one site in the network can 'alias' into inhomogeneities at the network level. This is most obvious when one site drops out of the network and thereby influences a spatial mean (and its uncertainty) calculated from the remaining sites. An example was presented how at one site the recalibration of the relative humidity, using the pre-flight specific humidity chamber (SHC) results, might affect site and network data inhomogeneity. It was shown that use of the specific humidity chamber ground-check information removes a real bias in the data and generates the best possible result for each individual measurement, but produces an inhomogeneous data series. For this particular case, if the specific humidity chamber ground-check information is not used to make the necessary bias correction, then a known bias is ignored and this becomes an issue for comparison with satellite and models. This presents a number of options, viz:

- To make bias corrections individually for each measurement i.e. always use the best approach to correct that particular measurement. This option may produce inhomogeneities in space and time.
- Use a method that is applicable to the site as a whole. Making such a correction could then introduce inhomogeneities in space.
- Use a method for a specific time i.e. use the best approach which is available at a given date for all sites. This option produces data series that are then inhomogeneous in time and may not be the best approach for any one site.
- Use a method specific to the entire data stream i.e. a method which is always available for all sites. This results in spatial and temporally homogeneous data series across the network, but not necessarily at any given site.

Exactly where on the spectrum of ensuring network-wide homogeneity at one end, and ensuring the best possible result for any single measurement at the other end, the GRUAN community wants to be, is something that needs to be decided on.

Outcomes from the subsequent discussion included:

- In addition to requiring network wide temporal and spatial homogeneity in the measurand, there is also a need for such homogeneity in the uncertainty on the measurand.
- Correcting for bias does, of course, also add to the uncertainty in the measurement.

5.2 Update on GRUAN's interactions with the WIGOS metadata task team. – Arnoud Apituley

Arnoud began by giving an overview of WIGOS and then summarized the WIGOS Framework Implementation Plan (WIP) which details the activities that WMO and its partners will undertake from 2012 to 2015 to establish an operational WIGOS by 2016. The plan focuses on integrating governance and management mechanisms, functions and activities among the contributing systems. The WIGOS goals include improving the quality and availability of data, improving the quality and availability of metadata, developing capacity, and improving access to data. Key implementation activities for WIGOS include:

- Management of WIGOS implementation,
- Collaboration with the WMO co-sponsored observing systems and international partner organizations and programmes,
- Design, planning and optimized evolution,
- Integrated observing system operation and maintenance,
- Integrated quality management,
- Standardization, systems interoperability and data compatibility,
- The WIGOS Operational Information Resource (WIR),
- Data discovery, delivery and archiving,
- Capacity Development,
- Communications and outreach

Regarding interaction on GRUAN metadata, the WIGOS 'Data discovery, delivery and archiving' implementation activity is most relevant to GRUAN. A WIGOS metadata standard is being defined by the Inter-Commission Coordination Group on the WMO Integrated Global Observing System (ICG-WIGOS) Task Team on WIGOS Metadata (TT-WMD). An important aspect of WIGOS implementation is ensuring maximum usefulness of WIGOS observations. Observations without metadata are of very limited use; it is only when accompanied by adequate metadata that the full potential of the observations can be realised. WIGOS identifies two complementary types of metadata (1) discovery metadata – information that facilitates data discovery, access and retrieval. These metadata are WIS metadata and are specified and handled as part of WIS, and (2) interpretation/description or observational metadata – information that enables data values to be interpreted in context. These metadata are WIGOS metadata. The WIGOS metadata standard provides the interpretation metadata required for the effective use of observations from all WIGOS component observing systems by all users.

To provide data users with confidence that the data are appropriate for their intended application, WIGOS metadata are expected to describe the observed variable, the conditions under which it was observed, how it was measured, and how the data have been processed. These metadata, including details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting the data are expected to be documented and treated with the same care as the data themselves.

The terms of reference for the Task Team on the WIGOS metadata are to:

a. Identify the information that is needed to allow the majority of users to use WIGOS observations in appropriate contexts and in a defensible way;
b. Create the WIGOS Core Metadata Standard that allows the essential information to be exchanged unambiguously, regardless of the format used for the transfer;
c. Define a mechanism for maintaining the WIGOS Core Metadata Standard, including how metadata might be provided that is additional to the Core and coordinate with the ICG-WIGOS Task Team on Regulatory Material on any appropriate documentation as needed for WIGOS related Manuals and Guides;
d. Implement within the WIGOS Core Metadata Standard, and the WMO Core Metadata Profile, a standard method of providing users with an indication of the quality of the data, and to do so in a way that distinguishes with the quality management of the data ("quality of the observation") and ensuring that the user is able to identify which applications the data are suitable for ("classification" of the observation");
e. Coordinate regularly with the ICG-WIGOS as needed and report at least annually to the ICG-WIGOS on the progress;
f. Complete its tasks and hand over additional requirements to its successor (if required) in time for approval by Cg-17.

Elements of the WIGOS metadata are classified as either:

- Mandatory: Important for all WMO Technical Commissions.
- Conditional: Must be reported under certain conditions.
- Optional: Provide useful information that can help to better understand an observation. As is to be expected for a 'core' metadata standard, very few elements are considered optional. Optional elements are likely to be important for a particular community, but less so for others.

In their creation of metadata guidelines, the TT-WMD has considered the space and time aspects of metadata: WIGOS metadata are intended to describe an individual observation or a dataset, i.e. one or several observations, including the where, when, how, and even why the observations were made. As a consequence, references to space and time are made in several places throughout the standard. The WIGOS metadata standard therefore needs to take into account such elements as the spatial extent of the observed variable, the geospatial location of the station/platform, the geospatial location of the instrument, and the spatial representativeness of the observation.

A station/platform can be:

- Collocated with the observed quantity as for in situ surface observing station (e.g. an Automatic Weather Station - AWS)
- Collocated with the instrument but remote to the observed quantity (e.g. radar)
- Remote from where the instrument may transmit data to the station (e.g. airport surface station where instruments are located across the airport, or a balloon atmosphere profiling station)

- In motion and travelling through the observed medium (e.g. AMDAR - Aircraft Meteorological Data Relay - equipped aircraft)
- In motion and remote to the observed medium (e.g. satellite platform)

An instrument can be:

- Collocated with the observed variable (e.g. surface temperature sensor)
- Remote to the observed variable (e.g. radar transmitter/receiver)
- In motion but located in the observed medium (e.g. radiosonde)
- In motion and remote from the observed quantity (e.g. satellite based radiometer)
- Located within a standardized enclosure (e.g. a temperature sensor within a Stevenson screen)

Regarding the technical implementation of the WIGOS metadata standard:

- The likely implementation will be XML (Extensible Mark-up Language), in line with the specifications for WIS metadata and common interoperability standards.
- Not all elements will need to be updated at the same frequency. Some elements (e.g. position of a land-based station) are time-invariant, while others (e.g. the position of a specific sensor) may change regularly. Still other elements, such as the environment, may change gradually or rarely, but perhaps abruptly.
- Not all applications of observations require the full suite of metadata. The quantity of metadata that needs to be provided to be able to make adequate use of an observation, for example for the purpose of issuing a heavy precipitation warning, is much less than for the adequate use of even the same observation for a climatological analysis. Metadata needed for near-real-time applications also needs to be provided in near-real-time.
- Users will need to filter datasets according to certain criteria/properties. This functionality requires either a central repository for WIGOS metadata or full interoperability of the archives collecting WIGOS metadata.

GRUAN will continue to remain engaged with the WIGOS metadata task team. The GRUAN co-chairs encouraged the Working Group to review the metadata documentation from WIGOS as this is important for GRUAN.

6. Other GRUAN products

6.1 GNSS-PW progress – Markus Bradke

Markus gave a summary of progress to date on developing the GRUAN GNSS-PW data product. As with other GRUAN data products, adherence to prescribed standards and conventions will be essential to ensuring the quality of the GNSS-PW data product. Markus outlined the requirements for the monument on which the GNSS receiver is placed. If the GNSS antenna is around 2m above an untilled, clear field then it should be possible to derive soil moisture. Markus then went on to discuss the requirements for the GNSS antenna. A key point is that if the antenna is changed, measurements need to be made with the old and new antenna configuration to determine if there are any systematic biases. Radomes should be avoided unless necessary to project the antenna from wildlife or the weather. Other considerations for radomes were also presented. GNSS receiver requirements were also summarized. An important recommendation is to use receivers that are capable of receiving signals from multiple GNSS constellations. The requirements for coincident meteorological measurements close to the GNSS receiver were also summarized. Markus then outlined the 5-step processing chain for GNSS data and the processes for archiving and distributing the GNSS-PW GRUAN data product. An important part of the processing is the conversion of receiver raw binary files to RINEX version 3 files. Processes have been established for the handling of GNSS metadata; the semisys (Sensor Meta Information System) tool will be essential for managing GRUAN metadata. A key issue is whether GRUAN should just use the GFZ metadata handling system or develop a new one. The goal is for the GNSS-PW GRUAN data product to be available by the time of ICM-8.

6.2 Lidar Progress - Thierry Leblanc

Thierry began by showing plots of upper-air (35-45 km altitude) time series of lidar-derived ozone and temperature, along with measurements from other instruments, from 1980 to the present for five NDACC sites. The GRUAN lidar programme covers the overall infrastructure underlying the lidar measurement and the subsequent production of a GRUAN lidar product, from data acquisition to data product management. The mandatory components of a GRUAN lidar programme include:

- The GRUAN Lidar Guide defining the complete framework of the Programme, from instrumentation to retrieval.
- A lidar instrument.
- Dedicated and motivated staff.
- An Individual GRUAN Lidar Instrumentation and Measurement Protocol (IGLIMP).
- The LidarRunClient utility for traceable data and meta data recording and upload. The LidarRunClient ingests metadata, including lidar configuration history, and uploads data to the centralized processing centre, including ancillary data (e.g., radiosonde launched during lidar integration period for calibration purposes).
- The centralized GRUAN Lidar Analysis Software Suite (GLASS) for consistent data processing. The GLASS provides for traceability, uncertainties documented, for water vapour, ozone and temperature. The GLASS checks the consistency of metadata, evaluates the quality of the data, propagates 10 different uncertainties in parallel to arrive at a total uncertainty.

While all current lidar sites have and use data processing software that has been developed in-house, the GLASS is needed for centralized lidar data processing to deliver a GRUAN lidar data product that is traceable, has a comprehensive uncertainty budget, provides standardized processing across the whole network, has the ability to reanalyse the raw data whenever needed, is sufficiently flexible that it can be tailored to meet all users' needs, and is well-documented and transparent.

Thierry then when on to show the flowchart of lidar data through the raw data quality check and the ingestion procedure which includes selecting the measurement date to process, a metadata consistency check, selecting/rejecting raw datasets based on their quality, selecting vertical sampling and time sampling, and starting the core data processing. A flow diagram of the core data processing for water vapour, temperature and ozone lidar measurements was then presented. Time and vertical sampling options can be tailored to meet different user needs and/or science applications. Products currently available through the GLASS include:

- Water vapour from the troposphere to 6-18 km depending on instrument)
  - Volume mixing ratio
  - Mass mixing ratio
  - Relative humidity (derived from mixing ratio using Hyland/Wexler w.r.t. water)
- Ozone, covering both the troposphere and stratosphere up to 50 km
  - Ozone number density
  - Ozone mixing ratio (derived from number density using the best available ancillary pressure and temperature profile)
- Temperature in stratosphere and mesosphere covering 12-90 km
  - Temperature
  - Air density and pressure (derived using lidar and best available ancillary pressure and temperature profile)

The following ‘pools’ of GRUAN lidar data products are available, each dedicated to meeting a specific user need and/or science application:

Use	Time average	Vertical resolution
Climatology and trends	Optimized for low noise (i.e., hours rather than minutes)	Optimized for low noise (i.e., km rather than m)
Process studies	Optimized for target science application (minutes to hours)	Optimized for target science application (m to km)
Redundancy and validation	Optimized to best match coincident measurement	Optimized to best match coincident measurement
Operational and assimilation	Optimized to best match assimilation scheme	Optimized to best match assimilation scheme

One instrument can produce GRUAN data products of one or several pools.

Thierry then showed 9 examples of GRUAN lidar data products, viz.:

1. *Climatology and trends:* Lidar water vapour profiles from Ny Ålesund, including the water vapour mixing ratio profile and the uncertainty budget for the profile, including individual uncertainty components.
2. *Process studies:* Multiple lidar water vapour profiles for a single day, separated by 30 minutes in time, as water vapour mixing ration and as relative humidity for Ny Ålesund.
3. *Climatology and trends:* Lidar water vapour profiles at Payerne as relative humidity profiles and including the combined uncertainty profiles and individual uncertainty components.
4. *Process studies:* Lidar water vapour profiles at Payerne as 30-minute time slices of water vapour mass mixing ratio and as relative humidity.
5. *Concept breakdown:* CIAO lidar water vapour profiles at Potenza as an example of where the standardization concept holds at ‘definition’ and ‘approach’ levels but breaks down at the quantitative estimates level. The key point is that every instrument yields a different answer regarding uncertainty.
6. *NDACC water vapour lidars:* Many NDACC (and non-NDACC) lidars measuring water vapour could be added to GRUAN. Examples of lidar water vapour profiles measured at the JPL Table Mountain facility were shown.
7. *NDACC stratospheric ozone lidars:* Many NDACC lidars measuring stratospheric ozone could be added to GRUAN. Examples of lidar ozone profiles measured at Maïdo, Reunion Island, were shown.
8. *NDACC temperature lidars:* Many NDACC lidars measuring temperature could be added to GRUAN. Examples of JPL lidar temperature profiles measured at Mauna Loa were shown.
9. *NDACC tropospheric ozone lidars:* Several tropospheric ozone lidars (NDACC and non-NDACC) could be added to GRUAN. Examples of tropospheric ozone profile measurements from the lidar at Huntsville were shown.

Thierry then summarized the current state of the GLASS. Data from more than 9 sites have been processed using the GLASS. Lidar data are calibrated using e.g. collocated or nearby radiosonde profiles, to reduce uncertainties. The GLASS is capable of a high degree of flexibility (time sampling, vertical sampling and vertical resolution, multiple options for range-merging optimization, multiple options for profile cut-off optimization) and can generate a comprehensive and ‘standardized’ uncertainty budget – there are ~10 independent uncertainty sources for each product and each uncertainty source is propagated in parallel and in a traceable way to the archived product. Progress through 2014 was slow due to lack of time. A remaining potential challenge is where, when and how raw lidar data will be archived and analyzed. Next steps include linking together the pieces of the puzzle (LidarRunClient+GLASS+IGLIMP) and automating data processing for centralized lidar data processing and provision of a GRUAN lidar data product. In addition to completing the LidarRunClient, resultant products need to be validated using multiple years of data products. The processing algorithm needs to be refined with alternate calibration methods added.

Outcomes from the subsequent discussion included:

- The question was raised as to why individual uncertainties appear to be larger than total uncertainties. The answer is that some uncertainties are not used in portions of the profile to calculate total uncertainties because the processing relies upon the more certain measurements at any point in the profile (so the uncertainties are moot as the measurements they are quantified for do not contribute).
- If there is too much automation in lidar data processing, this may not allow for enough unique input data from different lidars. The solution is that users need to inform development of the LidarRunClient exactly what they need to submit in terms of unique input data.
- Potenza volunteered to assist with the processing and archiving of GRUAN lidar data.
- The question was raised as to whether, in future, calibration will be provided as part of a GRUAN lidar data product. The answer was 'absolutely'.

6.3 Raman lidar observations in Payerne – Gianni Martucci

Gianni began by showing RALMO Raman Lidar water vapour measurements in the upper-troposphere and lower stratosphere at Payerne which is operated as part of NDACC. A 6-year time series of these measurements is available showing a clear annual cycle with a summer-time maximum and generally higher variability in summer.

This is a fully automatic Raman lidar that can operate during the day or night with a narrow field-of-view and bandwidth, using a high-powered laser. Gianni summarized the data pre-processing noting that there is no aerosol correction and no saturation correction for night-time measurements. The water vapour retrieval includes vertical filtering, calculation of the mixing ratio and uncertainty estimation. For the pre-processing, only night-time data with low background and sufficient signal to noise ratio are considered. External calibration is performed in the lower troposphere using the SnowWhite hygrometer as a reference. The drift in calibration, resulting from uneven aging of the photomultiplier tubes, needs to be corrected for with regular calibrations. At Payerne an internal automatic calibration of the nitrogen and water vapour aging factor of the photomultiplier tubes is now in place.

Gianni described the optimal estimation method used for the lidar retrieval. Optimal estimation is widely used in passive remote sensing. It provides full characterization of the retrieval (averaging kernel) and a full uncertainty budget on a profile by profile basis. It also provides an idea framework for combining measurements. The implementation of optimal estimation for the water vapour Raman lidar at Payerne is ongoing.

Gianni then showed tropospheric lidar water vapour and aerosol time series at four different altitude ranges: 570±80m, 1350±150m, 3850±150m and 7850±150m (all altitudes in metres above sea-level). Total back-scatter ratio time series show Saharan dust events as well as Central and southern European pollution. Tropospheric Pure-Rotational Raman (PRR) extinction and backscatter measurements were also shown. These are calculated using the total PRR, stokes and anti-stokes rotational signals to reduce the temperature dependence of the spectrum to a minimum. Results at 60m vertical resolution and 20 minute temporal resolution measured during the Canadian fires of 7-8 July 2013 were shown. Calibration and overlap corrections for the lidar retrieval were then discussed. The temporal variability of the overlap correction function peaks at 700m with ~50% relative change over 2012 to 2014. The mean standard deviation at altitudes below 5 km is 20%.

Measurements from the SOMORA stratospheric ozone monitoring radiometer over the period 2000 to 2014 were then shown. SOMORA operates at a centre frequency of 142 GHz with a bandwidth of 1 GHz and a resolution of 61 kHz to provide vertical ozone profiles from ~22 km to 55 km altitude.

Outcomes from the subsequent discussion included:

- The question was raised as to whether degradation of the lidar detectors reduces the measurement ceiling. This is indeed the case, which is why lidar calibrations are performed frequently to monitor such changes.

- While RALMO detectors had not yet been replaced, it was only a matter of time before this would be necessary.
- The Raman lidar at Payerne is capable of temperature retrievals, but was down for some time. It is now back up and running.

6.4 Progress towards GRUAN Microwave Radiometer product - Nico Cimini

Nico began by summarizing the role of microwave radiometer (MWR) measurements in GRUAN and the status of the GRUAN MWR Programme Guide (the MWR Technical Document). MWR will provide measurements of total column water vapour, total cloud liquid water as well as vertical profiles of temperature and water vapour to augment measurements from radiosondes, GNSS, Raman lidar and FTIR. In the past, MWR measurements have been used to diagnose a dry bias in RS80 radiosondes and a wet bias in the VIZ-B2/GPS Mark II microsonde. The high level of redundancy with radiosonde total column water vapour suggests that temporally and spatially collocated MWR and radiosonde measurements have the potential to reduce radiosonde random uncertainties. Because MWR operates continuously, it provides an important means of interpolating variability in e.g. vertical profiles of temperature and water vapour between radiosonde flights to elucidate diurnal cycles and shorter period temporal structure in those climate variables.

There is a range of different MWRs in operation at GRUAN sites with different capabilities and therefore delivering different products. A table was shown listing GRUAN sites, the different types of MWRs hosted by the sites, the instrument manufactures and their year of initiation.

A GRUAN MWR Technical Document, following the prescribed structure (GRUAN Technical Note 2), is in preparation. Some sections have been completed while others are still in development.

Validation of MWR measurements is done routinely at some GRUAN sites including Lindenberg, Payerne, and Lamont. Temperature and water vapour profiles are validated against radiosonde measurements while total column water vapour is validated against radiosondes, GNSS and Raman lidar. High quality MWR measurements require proper calibration and maintenance. MWR calibration relies on a combination of 2-3 methods which may include:

1. *Gain calibration:* very frequent (seconds) with noise diode sources.
2. *High-emissivity black-body targets:* 1 or 2 external black-body targets at T_{hot} and T_{cold}. Tight temperature control.
3. *Tipping curve:* airmass-opacity relationship. This is applicable to low-opacity channels only (e.g. 20-30 GHz). Side-views may be partially obstructed and a clear-sky may not always be available.
4. *Cryogenic calibration:* black-body target in a liquid nitrogen cryogenic bath. This calibration requires a high level of safety and training. Liquid nitrogen is not easily available at all sites and there is no standardized calibration procedure.

Nico went on to discuss the Joint Calibration Experiment that occurred in Lindenberg from 25-29 August 2014 where five MWRs were operated within 10m of each other. The objectives of the experiment were to develop standard protocols for optimum liquid nitrogen calibration, to characterize the liquid nitrogen calibration with regard to repeatability, stability, and random uncertainty.

Regular maintenance of MWR hardware is required to ensure a long operating life-time. This includes keeping liquid water off the radome, keeping the radome otherwise clean and undamaged which may require e.g. removal of dirt, sand and/or dust (depending on the operating environment).

Data quality management is already in place for many of the GRUAN MWRs. Quality flags are provided automatically through the metadata for internal sanity checks and wet/dirty radomes. Change management requires that old and new MWR instruments are operated side-by-side for at least one year. MWR data are provided as Climate and Forecast compliant NetCDF files as discussed and agreed within MWR-net. MWR measurements from Cabauw and Lindenberg, as well as other non-GRUAN sites, are already provided in this way. Additional metadata requirements for GRUAN still need to be discussed and agreed on.

The issue of whether MWR measurements can be accepted as reference measurements was raised in the context of:

- *Traceability:* Calibration relies on high-emissivity black-body targets. Traceability is partly achieved by a certified high temperature measurement and a liquid nitrogen low temperature measurement. While there are currently no microwave SI standards, the U.S. National Institute of Standards and Technology (NIST) is working on this. Over the next few years NIST expects to be able to provide SI-traceable T_b calibration for black-body targets and transfer standards in the form of calibrated black-body targets.
- *Uncertainty:* Information is available but needs to be generalized. Both calibration uncertainties and retrieval uncertainties (a priori, inversion method, absorption model) need to be evaluated. Estimated uncertainties need to be validated through comparisons against radiosonde profiles. Optimal estimation may be used to produce a retrieval uncertainty. The framework for estimating MWR measurement uncertainties is already in place.
- *Documentation:* Development of the GRUAN MWR Technical Document is nearing completion.

Nico finished the presentation by discussing results from MWR activities at Payerne/Bern including a temperature intercomparison campaign between radiosondes and two microwave radiometers, and a stratospheric temperature intercomparison involving radiosondes, a ground-based MWR, and a satellite-based MWR (MLS).

Outcomes from the subsequent discussion included:

- The question was raised as to whether Raman channels could be used for temperature retrievals. Nico replied that this should, in principle, be possible since all of the same people are involved.
- The comment was made that the approach to GRUAN MWR products should be limited to a few to finalize the uncertainties. The response was that we can build on the uncertainty framework for all MWR data products using established uncertainties from fundamental measurements.

6.5 MUSICA: FTIR H_2O data – Matthias Schneider

The scientific objective of MUSICA (**MU**lti-platform remote **S**ensing of **I**sotopologues for investigating the **C**ycle of **A**tmospheric water) is to use the isotopic signals in water vapour to constrain the tropospheric moisture pathways and the associated uncertainty in climate models. The first step and focus of MUSICA is to generate high quality observational data of H_2O and δD by combining different measurement techniques from different platforms. This includes providing reference data from calibrated in-situ observations, long-term data from a ground-based remote sensing network, and global coverage with space-based remote sensing. MUSICA works with a subset of NDACC stations where FTIRs produce long-term data sets with network-wide consistency. Vertical distribution information is available through pressure-broadening of absorption lines. The data are centrally processed at KIT. MUSICA incorporates a traceable processing chain that applies the PROFFIT retrieval code to perform retrievals and estimate associated uncertainties from measured spectra in a self-consistent way. 15,000 FTIR water vapour profile measurements are available from 10 sites, some from the mid-1990s. Matthias showed how, within MUSICA, the vertical sensitivity and error estimation are assessed for each individual observation at all stations.

The IASI (Infrared Atmospheric Sounding Interferometer) instrument uses the same PROFFIT retrieval code as the MUSICA FTIR. Matthias showed scatter plots of H_2O mixing ratios at different altitudes between IASI and ground-based FTIR at Izana, Karlsruhe and Kiruna (for more information see Wiegele et al., 2014).

Matthias went on to discuss the value of upper-air water vapour isotopologue data. Tropospheric moisture transport affects the transport of latent heat and the evolution of clouds, which in turn comprise uncertainties in climate models. Water vapour isotopologues can be used to diagnose moisture transport pathways and to compare these with those simulated in climate models. Free troposphere moisture transport pathways have been shown to determine model climate sensitivity (Sherwood et al., 2014). Ice-core water vapour isotopologues are also an important diagnostic tool in paleo-climate research.

One question that was asked was how the historical Jungfraujoch FTIR data fit into the current framework of FTIR measurements. The answer was that current records are with the newer Bruker FTIR; the quality of the older measurements needs evaluation.

7. GRUAN and satellites

7.1 Follow-on actions for GRUAN from the 3G workshop – Greg Bodeker representing Stephan Bojinski

The GRUAN-GSICS-GNSSRO (3G) WIGOS Workshop on Upper-Air Observing System Integration and Application took place from 6-8 May 2014 at WMO headquarters in Geneva, Switzerland. The attendance of the 22 experts was by invitation only. The objectives of the workshop were to:

- Identify measures to better connect GRUAN with the satellite community,
- Compare methods of measurement uncertainty estimation,
- Provide guidance on how the various observing systems and data sets can better serve meteorological and climate applications,
- Develop recommendations for future observing system design.

The workshop addressed key areas for WIGOS implementation and, in particular, sought to 'inform the development of guidance for sharing operational experiences, expertise, and joint exploitation of resources'. The workshop was framed as a WIGOS case study and benefited from WIGOS Project Office funding. Twenty recommendations were made at the technical and strategic level and have been written up in a workshop report[1]. Discussion highlights included:

- The overarching goal is a resilient and cost-effective overall observing system, best serving applications. 3G contributes to this end.
- It is important that GRUAN demonstrates its value to applications now and not just in 30 years' time.
- The importance of independent reference data sets is recognized in climate and NWP applications. These can help improve utility and quality of other observations such as GUAN although this still needs to be demonstrated.
- The benefit of a country for hosting a GRUAN site needs to be clearly articulated.
- Consistent uncertainty estimation and terminology across the 3G communities was recommended: comparability is important, and uncertainty information has many users.
- The 3G measurement networks should be maintained and quality controlled independently of each other.
- GRUAN data may be useful to calibrate satellite microwave sensors since there is no obvious on-orbit reference in GSICS.
- NWP centres want single-source data sets with uncertainties, not combined 2G/3G observational data sets.
- Uncertainty in spectroscopic libraries used in radiative transfer can affect observation uncertainty estimates (error covariance matrix). It was not clear who should solve this problem though.

It was clarified that 'integration' in the sense of the WMO Vision for 2015 means strong links between observing systems (sondes, hyper-infra-red, radio occultation etc.) and application communities (NWP, climate monitoring etc.) which then meet the needs of various services (weather, water, climate etc.).

Ongoing action highlights arising from the workshop included:

[1] Available at http://www.wmo.int/pages/prog/www/WIGOS-WIS/reports/3G-WIGOS-WS2014.pdf

- GRUAN best practices in using uncertainty terminology have been shared with other communities (3G-5).
- A prediction tool for availability of radio occultation profiles in space/time is useful for dedicated observations/launches (3G-7).
- Intercomparison of methods to estimate collocation uncertainties based on data from 3G, NWP fields, and SASBEs over 4 GRUAN sites (3G-9).
- Study has been commissioned to characterize radiosonde temperature biases and errors using radio occultation measurements and NWP background fields (EUMETSAT ROM SAF Visiting Scientist; 3G-11).

7.2 Accurate Occultation Prediction with 4 Weeks Lead Time/Statistical Analysis of COSMIC Radio Occultation Data against GRUAN Sondes – Axel von Engeln

Axel began with an overview of the NAPEOS (NAvigation Package for Earth Observation Satellites) software for precise orbit prediction (http://www.positim.com/napeos.html). For GPS orbits, the software provides the latest precise GPS orbits, as provided by the EPS/Metop GNSS service (GSN, which is then fitted with the NAPEOS model over 24 hours and propagated up to 30 days in advance. For LEO (Low Earth Orbit) satellites, the latest LEO near-real-time orbit derived over the last 7 days (where possible, COSMIC has larger coverage gaps) is fitted with the NAPEOS model (the 7 days give more stable orbits) and propagated over the next 30 days. For Metop, the first day of propagation was 1 September 2014 whereas for COSMIC it was 1 January 2009. It must be noted that EUMETSAT uses geometric dependent mean occultation position (0 km Straight-Line Tangent Altitude) while UCAR uses atmospheric dependent mean occultation position (40 km Straight-Line Tangent Altitude). Forecasts were generated with an in house occultation simulator up to 4 weeks in advance. Daily results were shown for weekly periods.

Version 2 GRUAN data were used to compute refractivity and compared to COSMIC/UCAR. COSMIC "offline" or "reprocessed 2013" data were used as well as ECMWF operational 12 hour forecasts at the RO position. Matching criteria from 1-5 h and 100-500 km were tested. Location data at 10 km in the sonde profile and at the mean tangent point for the RO were used. The impact of the atmosphere behaving as a non-ideal gas on GRUAN vs. COSMIC statistics was presented. At 20 km, altitudes generated from GRUAN temperature, pressure and water vapour using the hypsometric equation can be up to 1 m lower than altitudes generated from GRUAN geopotential and ROPP (Radio Occultation Processing Package) geopotential to altitude conversion. On the other hand, altitude generated from GRUAN temperature, pressure, and water vapour using non-ideal gas compressibility can be up to 10m higher than from ROPP. The ROPP Report on refractivity is available (Healy, 2009). GRUAN vs. COSMIC (reprocessed 2013) refractivity statistics were shown and compared to COSMIC/ECMWF (reprocessed 2013) refractivity statistics as well as temperature statistics. Statistics for comparisons of refractivity and temperature disaggregated by day and night were also shown.

Axel then gave a EUMETSAT Mission Overview. A primary focus for EUMETSAT is EPS (EUMETSAT Polar System) and EPS-SG (EPS-Second Generation). EPS-SG represents Europe's contribution to the future Joint Polar System (JPS), which is planned to be established from 2040 together with NOAA following on from the Initial Joint Polar System (IJPS). IJPS currently accounts for around 45% of the total error reduction on day 1 forecasts achieved by all types of observation ingested in real-time by NWP models. The EPS-SG Programme is expected to be one of the most important sources of satellite observations for all forecasts based on NWP in the 2020–2040 timeframe. An additional optional programme for EUMETSAT is Jason-CS. The Jason-CS Programme is EUMETSAT's direct contribution to the funding, development and implementation of the Sentinel-6 mission, also involving ESA, the EU and NOAA. Sentinel-6 aims to continue high precision ocean altimetry measurements in the 2020–2030 timeframe using two successive, identical satellites, Jason-CS-A and Jason-CS-B. A secondary objective of Sentinel-6 is to collect high resolution vertical profiles of temperature, using GNSS-RO, to assess temperature changes in the troposphere and stratosphere and to support NWP. EUMETSAT is leading the system definition and is responsible for the ground segment development; operations preparation and operations of both satellites, and will co-fund the second satellite, together with the European Commission.

EUMETSAT has also been engaged in a number of data reprocessing activities. They are currently reprocessing Metop-A and Metop-B data up to the end of 2014. The next step is reprocessing of CHAMP and COSMIC data which could be available by the end of 2015. Refractivity and temperature processing will take place at the ROM SAF after EUMETSAT data delivery.

Outcomes from the subsequent discussion included:

- The question was raised as to whether any GRUAN sites would benefit from the NAPEOS forecasts. Thierry Leblanc's lidar work was identified as a potential beneficiary.
- A comment was made that GRUAN sites should use the NAPEOS information to time radiosonde launches.
- The availability of advanced collocation data was seen as being extremely valuable.
- While it was seen as important to convince sites to launch radiosondes to coincide with overpasses, it was also recognized that most sites don't provide data at high enough altitudes.
- The GNSS-RO/GRUAN/GSICS meeting recommended a demonstration that coincident sonde launching with overpasses from GRUAN sites needs to be proven useful.

7.3 Consistency between GRUAN and IASI and the GRUAN/satellite collocation uncertainty determination project – Xavier Calbet

Xavier began by discussing why establishing the consistency between GRUAN and IASI measurements is important. Both GRUAN and IASI claim to provide reference measurements; GRUAN for the upper-air and IASA is the reference for GSICS. Validation of IASI is a prerequisite for adequate validation of other space-based measurements. The method used to establish consistency between IASI and GRUAN requires comparison of observed IASI radiances (hereafter referred to as OBS) with radiances calculated using GRUAN radiosonde temperature, pressure and humidity profiles as input to the LBLRTM 12.2 radiative transfer model (hereafter referred to as CALC). OBS-CALC should fall within ±3σ of the IASI instrument noise. 26 cases of such comparisons are available. These studies may be adversely affected by a 3% relative humidity bias in the GRUAN radiosonde profiles. This study can also be done using CFH and collocated sonde pairs which show a better level of agreement. While only 4 such cases were available, there are plans to extended this study in the future (see Calbet et al., 2011 for additional information).

Xavier then went on to talk about the 3G collocation uncertainty determination project. The related action from the 3G workshop was to develop a collocation uncertainty methodology for GRUAN vs. IR Hyperspectral vs. GNSS-RO on an individual basis. The project was divided into a number of phases including:

- Collocation of a limited sample to estimate the time and space window for collocation of all 3G data sources to obtain 2-3 examples per site.
- Exact determination of the time/space collocation window.
- Collection of data sets (GRUAN, IASI, CriS, AIRS, COSMIC, GRAS, ECMWF).
- Collocation uncertainty determination using available data.
- First results (description of the algorithms) are expected to be available in mid-2015.

A small data set of collocations has been established including 3 cases of triple collocations of GRUAN, IASI and GRAS and 2 cases of triple collocations of GRUAN, IASI and COSMIC. There was an expectation that more cases would be added in the near future. The collocation data are provided as collocation event files which are short ASCII files describing the collocation information (time, space, original data files, etc.) but without instrument data, and collocation data files which are in the original instrument format (as much as possible) and are provided as HDF5 or NetCDF files. These data have been made available on an FTP server[2].

Outcomes from the subsequent discussion included:

- The question was raised as to whether only clear-sky signals were used in the study. The answer was that while a complete database would be all sky, the study reported on was based only on clear-sky results.
- It was clarified that while GRUAN uncertainties were not included in the comparison, the uncertainties will likely fall within the IASI uncertainty range, but will be included in the future.
- Subsequent discussion will determine whether the Lead Centre will be responsible for hosting the collocation database.
- The data comparison will be extended to include other instruments and other sites.
- The question was raised as to whether SHADOZ data could be processed by GRUAN. The answer was that it was not sure that GRUAN requirements are met by SHADOZ sounding sites.

7.4 The H2020 GAIA-CLIM project – Peter Thorne

The purpose of the GAIA-CLIM project is to characterise satellite measurements using in-situ, ground-based and sub-orbital capabilities. The genesis of GAIA-CLIM was in a H2020 call which stated 'The proposal is expected to lead to significant advances in greater consistency and cross-calibration/validation of long-term space-based measurements with ground-based historical references, providing a better overview of uncertainty of available data to generate Climate Data Records, including information impacts of space data. Based on the work done, best practices regarding calibration/validation campaigns should be promoted'. A group led by several of the leads of GRUAN, NDACC and TCCON drafted a proposal concentrating on high quality measurement networks, traceability and uncertainty quantification, and delivering user tools. Specific actions in GAIA-CLIM relate to:

- Defining data quality attributes.
- Mapping by capabilities, i.e. defining tiers of data quality based on their characteristics, mapping these capabilities, providing a mapping tool to visualize the capabilities, and assessing geographical gaps in capabilities.
- Improving quantification of in-situ ground-based and sub-orbital measurements.
- Better quantifying the impacts of measurement mismatches. Satellites and other measures will never measure the exact same volume of air over the exact same time interval. There will be differences in time of observation (including measurement time integral mismatch and diurnal cycle effects), differences in horizontal geolocation, including such time-varying effects as drift of balloon-borne measurements, differences in vertical registration, especially in the presence of altitude uncertainties/shifts, differences in vertical smoothing (needed for vertical averaging kernels for both columnar and profile measurements), differences in horizontal smoothing (consider e.g. an in situ sonde with respect to a 300 km satellite horizontal resolution). There may also be confounding effects such as cloud impacts if comparing to radiances in the IR spectrum. GAIA-CLIM Work Package 3 will use models and statistical approaches to quantify the effects.
- Using Data Assimilation to improve the usefulness of high quality measurements. This 4th Work Package of GAIA-CLIM will investigate the value of using data assimilation and reference quality measurements. It will define biases in data assimilation, propagate information from point measures to more regionally / globally complete estimation, and investigate the use of these methods in both NWP and reanalyses.
- Providing useable and action-oriented information to end users to improve the value of both satellite and non-satellite data.

[2] ftp://ftp.eumetsat.int/pub/EUM/out/RSP/calbet/CollocationUncertaintyDetermination20150220.tgz

With regard to quantifying measurement uncertainties, GAIA-CLIM is considering measurements of temperature, humidity, CO_2, CH_4, ozone, aerosols, CO, HCHO and NO_2 from radiosondes, frostpoint hygrometers, ozonesondes, lidars, microwave radiometers, FTIR/FTS, UV/vis spectrometers, MAX-DOAS/Pandora spectrometers, and GNSS-PW (selected species for selected measurements).

Work Package 5 of GAIA-CLIM will build a virtual observatory to make the outcomes of the other Work Packages useable and action-oriented. This will require the creation of a collocation database, an assessment of the availability of level 1/level 2 comparisons including uncertainties, developing a graphical display and user interface, and building the virtual observatory with the expectation of it becoming a sustainable service.

Work Package 6 of GAIA-CLIM focusses on outreach and gaps assessment including:

- Gaps in geographical coverage and their impacts arising from the geographical mapping exercise,
- Gaps in knowledge of measurement properties and uncertainties for both specific instrument types and on an ECV basis,
- Gaps in understanding of the impact of measurement mismatches arising from inadequacies in knowledge of how to deal with measurement mismatch issues,
- Open issues regarding how to use dynamical model and data assimilation techniques as integrators,
- Issues that remain in enabling easy use of reference quality measures as calibration/validation tools,
- Gaps between user needs and current observational and analysis capabilities,
- Consideration to the somewhat fractured nature of observing systems.

7.5 Progress with NPROVS+ – Tony Reale

Tony began by providing an overview of NPROVS+. Given a radiosonde launch time/location, NPROVS+ identifies all satellite soundings within +7 to -6 hours and 150 km (250 km for GPSRO) of the radiosonde. For NPROVS, the single closest satellite observation in time, then space, was selected and stored. For NPROVS+ the single closest, as well as all satellite soundings within 250 km, of the radiosonde location are stored. For NPROVS+ the sensor data records (for S-NPP) are also appended. A similar approach is followed for all satellite-collocation data records. This is done for each radiosonde observation. These are compiled into daily data sets and maintained in long-term collocation archives. Tony showed a typical NPROVS collocation map, indicating about 1000 collocations per day, as well as a range of different output from the NPROVS+ system including the EDGE analytical interface, routine monitoring to deep dive, and graphical output from the profile display software. The NPROVS collocation files, as well as two Java apps (PDISP and NARCS), can be downloaded from the NPROVS website[3].

Tony then went on to demonstrate how NPROVS+ is serving GRUAN. Because NPROVS+ operates in a 7-day delay mode, availability of GRUAN observations within that 7-day window is important to facilitate collocation with multiple satellite data systems. Unfortunately, many sites do not meet this delivery window. Comparisons of GRUAN Vaisala RS92 temperature profiles against COSMIC radio occultation dry temperature profiles were shown together with comparisons against ECMWF analysis. While day-time comparisons show a warm bias in the GRUAN measurements, this bias becomes statistically insignificant for night-time comparisons. A similar pattern is seen for Modem radiosondes. An analysis of k values ($m_1 - m_2 = k\sqrt{\sigma^2 + u_1^2 + u_2^2}$) indicates that radiosondes appear to be measuring relative humidity with higher confidence than temperature.

Outcomes from the subsequent discussion included:

- The question was raised as to whether the timeliness of data submission was based in its appearance on the GTS. The answer was likely ‘yes’ but it was not completely clear.

[3] http://www.star.nesdis.noaa.gov/smcd/opdb/nprovs/

7.6 GPS-RO water vapour and GRUAN – Rob Kursinski

Rob began with a summary of the GNSS-RO method including a description of the equations underlying the retrieval of temperature and pressure profiles from RO measurements of refractivity. In regards to what GNSS-RO offers for water vapour retrievals, the refractivity is sensitive to tropospheric water vapour and the bending angle is particularly sensitive to water vapour. GNSS-RO can provide very high vertical resolution (~200 m) profiles of water vapour which are useful for resolving the scale of variations in water vapour seen from other instruments. The horizontal resolution of the GNSS-RO water vapour measurement is ~70 km. GNSS-RO is capable of profiling through clouds to observe very wet air in and below clouds. The focus for RO retrievals is usually on the free troposphere as this avoids the super-refraction problem. The anticipated impact of GNSS-RO humidity information on NWP has not yet materialized primarily because GNSS-RO sampling has, to date, been very sparse globally.

There are a number of features that make GNSS-RO retrievals attractive for use in atmospheric research, viz.:

- They provide one of the least biased data sets available.
- They provide global coverage.
- With a constellation of 6 or more satellites (such as COSMIC), they provide diurnal coverage.
- Due to the operational wavelength of ~20 cm, they work in both clear and cloudy conditions.
- The retrievals are insensitive to surface emissivity and so work over land and water.
- Except under conditions of super-refraction, there is a unique relation between bending angle and refractivity which makes the retrieval insensitive to the initial guess.
- The vertical range extends to 240 K in the tropics (~9 km altitude at low latitudes), and can go colder and higher if retrieving zonal averages. In the extra-tropics the retrieved profiles extend to close to the surface. If the effects of super-refraction can be dealt with, the profiles can be extended down to the surface also at low latitudes.

The two methods for extracting water vapour from GNSS-RO refractivity profiles were presented, namely the Direct Method and the (1D) Variational Method. The Direct Methods determines the dry refractivity from analysis temperature profiles and the hydrostatic equations and then scale the wet refractivity to retrieve the water vapour profile. The Variational Method combines GNSS refractivity with analysis temperatures, water vapour profiles and surface pressure, as well as error covariance estimates, in an over-determined least squares solution. The Direct Method has the advantages of not being affected by biases in background water vapour forecast/analysis and can be used to derive water vapour information to higher altitudes. However, the Direct Method produces unphysical, negative water vapour values in histograms of water vapour concentrations. This can be fixed by deconvolving the error distribution from histograms. The method is described further in Kursinski and Gebhardt (2014). The process for estimating the accuracy of GNSS-derived water vapour profiles was then presented. The process, described in Kursinski and Hajj (2001), combines uncertainties resulting from refractivity, temperature and pressure from GNSS.

7.7 Active Temperature Ozone and Moisture Microwave Spectrometer ATOMMS – Rob Kursinski

This second presentation by Rob started by posing the question ‘What could you do if you were to design an RO system from scratch?’ with the answer being that you would build an RO system that probes the 22 & 183 GHz water vapour absorption lines. It would be an open air spectrometer that provides profiles of water vapour, temperature and pressure simultaneously, unlike GNSS RO, to much higher altitudes. Essentially it would be a cross between GNSS RO and the MLS (Microwave Limb Sounder) satellite-based instrument. This would eventually result in a low-Earth orbit constellation of ATOMMS. A combined 22 and 183 GHz RO active spectrometer would combine RO and attenuation of light (unlike RO) in a single, simultaneous retrieval of water vapour, temperature and pressure. Such retrievals would be possible in clear and cloudy air and over both land and water. Retrievals would include liquid water content, ozone, NO_2, water isotopes, line-of-sight winds above 10 hPa and turbulence. The RO would be self-calibrating and would therefore be free of drift. Expected resolution would be ~100 m in the vertical and ~50 km in the horizontal. For water vapour, the random uncertainty would be <3% and the systematic error <1%.

For temperature, a 0.4 K random uncertainty and a 0.05 K systematic error would be expected. The instrument would also provide unique profiles of turbulence from orbit.

The doubly differential absorption measurements would derive the optical depth from the change in signal level during occultation relative to the signal level measured above the atmosphere before or after each occultation. In this way, the instrument would be self-calibrating. The signal amplitude only has to be stable over ~100 seconds during an occultation to achieve climate quality stability. This will result in no long-term drift in the resultant measurement time series. The doubly differential absorption measurements would use two or more simultaneous tones in the retrieval. The first tone would be on an absorption line and the second would be a calibration tone off the absorption line. This two tone amplitude ratio method eliminates common mode noise and enables profiling in both clouds and rain, and also enables profiling of the cloud liquid water content. Finally, this method isolates and reduces or removes turbulent scintillations which can complicate retrievals.

Rob showed the near-surface random uncertainty that can be achieved using 3, 22 and 183 GHz tones, for temperature and water vapour, in the sub-Antarctic winter and in the tropics. Results from a ground-based prototype instrument were shown. The 183 GHz line shape spectroscopy agreement is better than 0.3% which is 10 times better than previous best spectroscopy. ATOMMS water vapour estimates agree with capacitive hygrometer measurements to 1%. For additional information on the instrument and its retrievals see Kursinski et al. (2012). Mountain top observations have been used to demonstrate water vapour retrievals from water vapour spectra measured under clear cloudy and raining conditions. These retrievals are enabled by a calibration tone at 198.6 GHz.

As an example of the use of the instrument, Rob showed how it might be used for high latitude profiling. These measurements would be highly relevant since there is a large spread amongst sea ice melting predictions. This uncertainty results from uncertainties in modelled clouds and energy fluxes. There is therefore an urgent need for additional observations to resolve these uncertainties. Passive observations are limited by vertical resolution and sensitivity to surface emissivity. The ATOMMS instrument would routinely profile atmospheric structure to the surface. These measurements would be insensitive to surface emissivity. Temperature, water vapour and pressure profiles, resolved at 100 m vertical resolution and 50 km horizontal resolution, somewhat like a sonde but with smaller random uncertainties, would be retrieved. The measurements would resolve near surface temperature, stability and moisture structures. The measurements would also include liquid water cloud presence, cloud liquid water content, and cloud temperature. As such, ATOMMS would fill a data sparse region of the globe with precise vertical profile observations particularly near the surface, to tightly constrain and quantitatively understand convection, sensible and latent heat fluxes, clouds and radiative transfer. The measurements would complement both CloudSat and Calipso measurements. New compact instrument designs are being developed for deploying the instrument on a WB57 high altitude aircraft and for deployment on a low Earth orbit satellite.

Outcomes from the subsequent discussion included:

- The question was raised as to whether the 22 GHz band could be used since there was a concern that this could interfere with spacecraft operations when ATOMMS is in orbit. The answer was that these are pure monochromatic tones at permitted wavelengths and are therefore undetectable by space operations.

8. Extending GRUAN's reach

8.1 GRUAN and GUAN –Tim Oakley

Tim began by providing an overview of the GCOS vision which is that all users have access to the climate observations, data records and information which they require to address pressing climate-related concerns. GCOS users include individuals, national and international organizations, institutions and agencies. The role of GCOS is to work with partners to ensure the sustained provision of reliable physical, chemical and biological observations and data records for the total climate system – across the atmospheric, oceanic and terrestrial domains, including hydrological and carbon cycles and the cryosphere. GCOS is concerned with the observations, data transmission, data management (including data rescue) and data products.

The GCOS Upper-Air Network (GUAN) comprises 171 stations distributed nearly homogeneously globally. The GCOS minimum requirements for GUAN sites are:

- Vertical temperature profile measurements to 30hPa.
- Vertical humidity profile measurements to the tropopause.
- Vertical wind direction and wind speed profile measurements to 30hPa.
- Measurements on at least 25 days each month.
- Data reported via TEMP messages.
- Data conforming to BUFR & 100hPa observations minus background (monthly) criteria.

A map for November 2014 was shown detailing the percentage of 100 hPa temperature data for 00/12 UTC received at ECMWF. While many sites are providing between 90 and 100% of the expected data volumes, there are also sites (e.g. in East Africa) providing less than 1% of the expected data. Lead Centres for GUAN in each of the six WMO regions take responsibility for managing GUAN sites in their region. A network manager communicates with sites and data users throughout the quality management chain, resolves more complex incidents, reports back to GCOS and its sponsors, directly engages with station staff and managers, oversees network improvement projects, introduces improvements in the quality management process, interacts with expert teams, projects, regional associations and sponsors. Challenges associated with the management of GUAN include dealing with a complex communication chain (global) which, at times, requires a good technical knowledge of the end to end process, GUAN is reliant on a number of centres who do this work as an added task (no additional resources), the management structure is passive (there is no threat of sites being ejected from the network), there is no real-time monitoring/action, both for station operators and/or network managers, and much of the monitoring does not work with the BUFR format. GCOS is working with WIGOS to improve this situation for the future. Tim pointed out the clear links required between GRUAN and GUAN. These links need to be documented and agreed upon. The benefit and resources arising from closer links between GRUAN and GUAN need to be explained and made available to station and network managers, as well as to NMHSs. GRUAN needs WMO (CBS) recognition through WIGOS. GRUAN can provide the scientific lead and guidance to WMO Members (and WMO commissions). GUAN stations with autosonde capabilities outperform manual sonde launch stations. Autosonde launchers use the same balloon regardless of environmental conditions (e.g., night/day) with the result that the burst height is more variable and lower height bursts more common.

An overview of the WIGOS observing network design principles was then given including the need for a tiered approach through which information from reference observations of high quality can be transferred to and used to improve the quality and utility of other observations. Furthermore, there is a need to provide information so that the observations can be interpreted. Observing networks should be designed and operated in such a way that the details and history of instruments, their environments and operating conditions, their data processing procedures and other factors pertinent to the understanding and interpretation of the observational data (i.e. metadata) are documented and treated with the same care as the data themselves.

Outcomes from the subsequent discussion included:

- The question was raised as to the AOPC recommendations (GCOS-182) for GUAN where anticipated to be implemented. The answer was that regulations cannot be pushed into stations. Rather the plan is to implement a ‘platform’ for improvements in GUAN operations and work with a subset of GUAN stations for improvements before expanding to other stations.
- There are definitely things that GRUAN can do for GUAN e.g. a better radiosonde processing package and implementation of better pre-flight checks. There was agreement at ICM-6 that this is possible.

- The question was raised as to whether at some time in the future GUAN sites should be GRUAN certified. The answer was that to take GUAN to the next stage there should be some level of certification.
- The question was asked as to the reason why burst heights change more with the use of auto-launchers. The answer is that the use of auto-sonde launchers limits the balloon size and a greater variation in burst height because of a large range of launch conditions and no range in balloon size.
- The question was asked as to why extra effort should be invested in BUFR format reporting if the additional data are not be used. The answer was that monitoring of BUFR is resource-limited and needs to improve.
- The question was asked as to whether archiving of hi-res BUFR is a solution. The answer was that archiving is different to monitoring of incoming data.

8.2 Collaborations in GNSS sphere with other projects (E-GVAP, COST Action GNSS4SWEC and EUREF) – Rosa Pacione / Jonathan Jones

Rosa began by providing a timeline of European GNSS-Met projects followed by a summary of the current status of E-GVAP. The EIG EUMETNET project is coordinating the near real-time delivery of data from ~2400 GPS sites delivering more than 14 million zenith total delay (ZTD) measurements each month. The focus is on GPS-only hourly processing that delivers only ZTD within 90 minutes. Operational assimilation of these data is underway at a few European NMHSs with testing underway at others. The use of E-GVAP ZTDs has proven to have a positive impact on NWP forecast skill. Surface temperature and pressure measurements can be used to convert the measurements to integrated precipitable water vapour. Active quality control of the data has been implemented. New hi-resolution NWP models require ZTD measurements with improved timeliness and greater spatial and temporal resolutions than are currently available. Observations providing additional information concerning tropospheric water vapour are also desired. Sub-hourly processing greatly increases the usefulness of GNSS products for now-casting and integrated precipitable water vapour displays. Only recently has the climate community (e.g. the Hadley Centre) started to use GNSS tropospheric products. The use of GPS meteorology for quantifying water vapour trends was discussed. These data can be used for long-term model validation; the NCEP model shows good seasonal and inter-annual variability in integrated precipitable water vapour but underestimates integrated precipitable water vapour by <40% in the tropics and <25% in Antarctica. GNSS derived integrated precipitable water vapour trends are a global trend of -1.65 to +2.32 kg m^{-2} per decade with an uncertainty of 0.21 to +1.52 kg m^{-2} per decade. There are regional increases in integrated precipitable water vapour over south-seat Asia and Australia.

An overview was given of the COST action GNSS4SWEC activity that has a 4 year action plan (2013-2017), includes 29 COST countries, 5 non-European Union countries, and over 100 participants from 60 institutions. The GNSS4SWEC working groups include a working group on advanced GNSS processing techniques, a working group on GNSS for severe weather monitoring, and a working group on GNSS for climate monitoring. The main aims of the action are to:

- Coordinate the development of new, multi-GNSS techniques and products.
- Improve the understanding of short-term atmospheric processes.
- Promote the use of, and determine the impact of, re-processed long-term GNSS tropospheric data sets for climate.
- Link its activities to the IGS and EUREF, and work in support of E-GVAP.
- Coordinate the exploitation of GNSS and meteorological data for mutual benefit.
- Lead to a consolidation of collaborating groups.

9. GRUAN sites

9.1 Lead Centre summary of site status and reports as in ICM-6 – Ruud Dirksen and GRUAN data flow from Lead Centre upload to GTS – Lead Centre and sites

Ruud began by providing an overview of the sites status and reports (these reports are available in Appendix E) and the processing chain for GRUAN data. The GRUAN 'DNA plot' for the previous year (2014) was then shown. This plot provides a graphical representation of the performance of each site for a given data stream. The plot highlights both reporting frequency and the quality of the data for each observation. The plots provide an easy way of ascertaining issues and activities. Ruud went on to highlight a number of generic issues including:

- Many sites fail on altitude attainment of balloons. Greater efforts need to be made to improve the burst pressures for the balloons – the target is 10hPa.
- There are issues with the metadata upload whereby different types of launches are not properly denoted which complicates interpretation. All sites must use the RSLaunchClient software to submit their data and to ensure the metadata being submitted are appropriate.
- The mix of some sites doing the standard humidity chamber ground-check and others not doing this is an issue. Sites must implement this check.
- Timeliness. The sounding data must be submitted to the GRUAN central data processing facility directly after the sounding. This is important for providing timely quality feedback and to aid satellite validation.

The GRUAN website now has a capability to view updates on the status of individual profiles that is available in near real time. This feedback will be further improved in Version 3 of the GRUAN data product with feedback provided to the sites as requested by the task team of site representatives.

The site reports consist of an automated Lead Centre processed summary and then additional information optionally provided by the site representatives. The Lead Centre generated content is identical across all sites enabling easy comparisons by the sites and end-users. It provides an inventory of data that includes data streams not yet processed but which will be able to be processed in the future.

Finally, Ruud highlighted the current status of Near Real Time (NRT) exchange over the GTS. This solicited substantial discussion. Greg Bodeker raised a concern that the situation was not seemingly advanced from that at ICM-6. Peter Thorne highlighted that the Lead Centre and Working Group had limited knowledge of or capability to support the sites and that help was needed from WMO. Roger Atkinson agreed that WMO should work with the Lead Centre to help sites reporting BUFR over the GTS. Tim Oakley cautioned against portraying such help as making a special case of GRUAN. It was agreed by all participants that we want BUFR from all sites globally and not just GRUAN. However, if we can't manage to get this for GRUAN sites it does not portend well for the chances of switching all GUAN sites, or the broader GOS, to BUFR.

Marion Maturilli queried whether BUFR should be a formal condition of acceptance. Peter Thorne clarified that it is not possible to make this an absolute requirement as the GRUAN Guide and GRUAN Manual state that delivery of NRT data over the GTS is strongly encouraged but did not stipulate an absolute requirement. Dale Hurst queried the value that would accrue from a weekly BUFR message from sites such as Boulder. Roger Atkinson clarified that absolutely everything helps. He further clarified that data from remote locations are particularly useful. Holger Vömel further noted that ECMWF and others can add metadata from data assimilation if BUFR-formatted data are exchanged.

Tim Oakley noted that BUFR-formatted data could be created at the Lead Centre if exchanged quickly and that the Lead Centre is a node on the WIS. He wondered whether the Lead Centre could include uncertainties and retransmit BUFR with GRUAN uncertainties. Ruud queried whether the existing BUFR format allows such functionality. Tim Oakley noted that certainly quality flags were catered for but was unsure whether uncertainty information transmission was possible. If it is not, then we need WMO to help make it possible so that GRUAN data can be exchanged. This will be reported back at ICM-8 to inform strategic discussions regarding potential NRT GRUAN data transmission in future.

Peter Thorne highlighted that BUFR is only part of the challenge. The absence of sites listed in Pub A is a real issue. For example, the Southern Great Plains site is not in Pub A and so UKMO and ECMWF had not been using the data from this site. Ingesting these data would have really helped with the current North American situation. Roger Atkinson clarified that Pub A will be completely regenerated as part of WIGOS. All GRUAN sites should end up in OSCAR and should be able to ensure, via the web, that the information in OSCAT is current. Tom Gardiner cautioned about potential confusion between the manufacturer processed data and the GRUAN data. It is necessary to be aware of this. The BUFR messages presently do not identify GRUAN processed data and the distinction matters scientifically.

There were queries raised about the quality flags assessment. Tom Gardiner queried what the predominant reasons were for flagging. Ruud clarified that it is primarily data quality issues but is not currently split out. Dale Hurst queried whether the feedback in the Version 3 data processing would provide further granularity. Ruud confirmed that this should be possible. Hannu Jauhiainen suggested that it would be useful to know which cases were metadata, which were balloon and which were instrument based. June Wang suggested that the DNA plot is somewhat misleading and would like to see, in addition, the percentage of green, yellow and red at both monthly and annual timescales.

Peter Thorne queried whether it is the standard humidity chamber ground-check that is increasing the check rate at sites that don't use it that is leading to the inter-site discrepancies in performance. Ruud said that he would need to check. Dale Hurst asked about whether the standard humidity chamber ground check data is intended to be in the metadata, in the data file, or in both. Ruud clarified that the standard humidity chamber checks should be in the metadata file ideally with the data from the check included. Richard Querel queried whether resubmission of the data stream was needed to resubmit with the correct check data. He further wished to clarify whether the radiosonde should be in the standard humidity chamber for at least 8 minutes. Ruud said data could be resubmitted and clarified that the RS92 should be in the standard humidity chamber for 8 minutes to permit two complete cycles of the humidity sensors.

Peter Thorne noted that Xilin Hot was not published in the pre-meeting material but will be in the final report. He requested that we should drop the two tropical western Pacific stations and include Paris and La Reunion next year. He further queried which sites should be approached to certify this coming year. It was agreed that the ARM programme sites would be invited and the Lead Centre and ARM agreed to work to this end. This would include at least SGP and NSA and may include NEA.

9.2 FLEXPART Lagrangian model for La Reunion and other activities at La Reunion - Stephanie Evan

Stephanie provided an overview of La Reunion activities with a focus on Lagrangian modelling. La Reunion has a mix of sounding and in-situ capabilities to study the southern Indian Ocean region. These make it an extremely promising GRUAN candidate site. Lagrangian modelling can help to optimze the observational sampling strategy to observe interesting features. La Reunion has launched some CFH sondes in the past year. A new proposal includes equipment costs that would cover CFH launches for three years. The MORGANE (Maïdo ObservatoRy Gas and Aerosols NDACC Experiment) campaign will occur in 2015 and include RS92/Modem/CFH/ ozonesonde and Maido and NASA lidars. Thierry Leblanc pointed out that using trajectories is always exciting but can lead to unrepresentative sampling of air-mass origins such that you end up biasing the long-term record. One should ensure a baseline capability as well. Stephanie clarified that these would be extra measurements. Thierry said that there is still an issue of sampling that could arise unless properly flagged as process study observations to avoid their use in trend based analyses.

9.3 Measurement at Sodankylä – Rigel Kivi

Rigel provided an overview of recent activities at Sodankylä. The site has undertaken comparisons including CFH, RS41, RS92 and RR01. Sodankylä has now launched in excess of 50,000 radiosondes. There have been between 6 and 12 CFH launches per year, together with RS92 and RS41 radiosondes, and some FLASH launches. In addition, RR01 launches have continued. The RS41 wintertime stratosphere is picking some signal in humidity but not the fine detail apparent in the CFH data. The RS41 is somewhat closer to CFH than RS92 in the stratosphere but there is still a distinct difference. Sodankylä has used RS41 with an ozone sounding. The RS41 is mounted high to avoid contamination by the ozonesonde housing. Experimental AirCore flights provide the potential to sample trace gas profiles based on in-situ sampling. Sodankylä has plans to undertake experiments on controlled descent and comparisons with meteolabor. June Wang asked about plans for RR01. Hannu Jauhiainen clarified that the RR01 is still under development. Its performance in the stratosphere is still a little moist compared to the CFH. Hannu queried whether there is a need for a measurement that is closer to the truth but easy to use.

9.4 Attempts to extend the Ny-Ålesund dataset backwards – Marion Maturilli

Activities at Ny Ålesund were updated by Marion with a focus on extending the radiosonde data set backwards in time. At the surface, warming has been greatest in winter. During these months there is no incoming solar radiation. Since its inception in 1993, the site has used RS80, RS90 and RS92 radiosondes but there was no overlap between programmes. Various corrections have been applied based on publications for the RS80 and RS90. The RS92 data since 2006 have been reprocessed using GRUAN processing. The standard humidity chamber checks started in 2005 so full GRUAN processing has been possible. The corrections to the relative humidity are large prior to use of the RS92 radiosonde reflecting dry biases in early instruments at higher altitudes. There have been substantial changes in winter – fewer ice clouds and more lowermost mixed-phase clouds. There has been an increase in the 90th percentile of integrated precipitable water vapour which has been substantial. The data set is intended to be published with 50 m vertical resolution (100 m in stratosphere). During the discussion it was pointed out that regime based analysis could be used to separate local from circulation effects.

9.5 Meteomet collaboration with Ny Ålesund – Andrea Merlone

Andrea summarized recent metrological activities undertaken in the framework of MeteoMet at Ny Ålesund. This included calibration using a reference chamber based on National Metrological Institute standards. Several instruments at Ny Ålesund were calibrated to ensure comparability between different measurements. Calibration uncertainty was undertaken for the instrument that was used to provide an independent ground check for the sondes. Thierry Leblanc questioned why the pressure calibration was not undertaken over a radiosonde pressure range. Andrea said this would be possible but was not requested but could be done in future. Holger Vömel asked whether radiation effects of the hut were characterised. Andrea responded that this was not covered but was in principle possible to investigate.

9.6 Update on Lauder activities– Richard Querel

Richard provided an update on activities at Lauder and Arrival Heights. Lauder researchers are writing a paper that compares vertical ozone profile and total column ozone measurements from lidar Dobson spectrophotometer, ozonesondes, FTIR and microwave radiometers. There is a certification event happening 10 March 2015 with NIWA and the New Zealand MetService in attendance. Lauder now has a WMO ID and the Digicora is being configured. Lauder will transmit BUFR-encoded messages to the New Zealand MetService for distribution via the GTS. Peter Thorne recognized the substantive effort on getting Lauder data distributed via the GTS. It was queried whether the Deep Wave campaign radiosonde data would be available and shared with the Lead Centre. Richard stated that the RS92 launches have now been shared and that there were also some GRAW launches which could be shared. Dian Seidel queried the viability of Arrival Heights as a future GRUAN site. Richard clarified that the key issue is the lack of a radiosonde programme. Greg Bodeker pointed out that McMurdo is very close and, together, McMurdo and Arrival Heights these could be considered as a single GRUAN site. McMurdo does run a radiosonde programme.

9.7 Metrology/meteorology at Potenza: perspectives – Fabio Madonna

Fabio provided an overview of work at Potenza. Collaboration with INRiM is leading to the possible establishment of a calibration laboratory at Potenza for in-situ and ground-based instruments. In the first instance, this will be for surface measurements with a later extension to upper-air capabilities including calibration of temperature, pressure and humidity sensors at different altitudes. Regular weekly manual sonde launches have started that also perform the standard humidity chamber tests. The site is exploring increased cooperation with the Italian Met Service. This may include transitioning to a daily launch schedule in the longer term although is not a certainty at the present time. The autosonde launcher has an issue with the ground-check. Potenza has offered help to analyse the effects of the use of an autosonde launcher. Potenza will also contribute to the development of the microwave radiometer product. Potenza is also working to be able to transmit data over the GTS.

9.8 NWS-Sterling NASA/GSFC and Beltsville collaboration – Belay Demoz

Belay began by pointing out that the application for site certification had been submitted. A current challenge facing the site, and the reason for most of the detected failures in the GRUAN DNA plots, is the low burst altitudes for the radiosonde balloons. The Beltsville site serves many masters including NASA, NOAA, Howard University, and University of Maryland. Monthly CFH flights from Beltsville have started. Coordination with the SHADOZ network and the TOLNet lidar has commenced. A number of student-led projects were presented including developing a vertical ozone profile climatology for Beltsville, satellite-sonde-lidar validation, quantifying wind speed and direction variability, and deriving temperature and moisture changes from satellite-based instruments. Belay finished by presenting a vision for a NWS-Sterling role in GRUAN. Sterling hopes to grow their facility and feels that they can play a major role in GRUAN in the future. Mike Hicks is working with NIST to update NWS laboratory facilities.

9.9 ARM Climate Research Facility - Doug Sisterson

The mission of the ARM climate research facility is to provide the climate research community with strategically located in situ and remote sensing observatories designed to improve the understand and representation, in climate and Earth system models, of clouds and aerosols as well as their interactions and coupling with the Earth’s surface. The vision is to provide a detailed and accurate description of the Earth’s atmosphere in diverse climate regimes to resolve the uncertainties in climate and Earth system models towards the development of sustainable solutions for the nation’s energy and environmental challenges. ARM contracts ~50 instrument mentors to oversee the operation, documentation, training of local site operations personnel, calibration, and data quality of all the ARM facility instruments. This includes more than 325 individual instruments, representing nearly 3,000 total data streams generating up to ~1 TB of data per day. Doug gave a description of the new Eastern North Atlantic (ENA) ARM site established on the Azores in 2013. The Azores are a region characterized by marine stratocumulus clouds, a major source of uncertainty in global climate models. The sites hosts a wide range of aerosol instrumentation, instruments for measuring the atmospheric and boundary state, lidars, radars and radiometers. The second of the three fixed ARM sites is the NSA (North Slope Alaska) site at Barrow, established in 1997. Instrument systems at NSA include solar and infrared broadband radiometric instruments, a Fourier transform infrared radiometer, cloud lidars and radars, a radar wind profiler, a radiosonde system, a sky imager, and microwave radiometers. Recent additions include three new dual-frequency scanning cloud radars that provide three-dimensional information about cloud properties, an eddy correlation (ECOR) flux measurement system and complementary surface energy balance system (SEBS); high spectral resolution lidar; and a launching system for automated release of weather balloons. The SGP (Southern Great Plains) site is a study area that consists of ~25-30 in-situ and remote sensing instrument clusters arrayed across approximately 143,000 square kilometres in north-central Oklahoma. Doug provided an overview of the facilities available at SGP, a brief history of the site, the site configuration as of 2010, and the SGP Central Facility layout. He also provided some indications of the future of ARM. The ARM Facility is now embarking on a reconfiguration strategy for even better observations of atmospheric processes to constrain high resolution process models. Key elements of the new strategy include the creation of two ‘super sites’ in the United States. Measurements at the SGP Site will be augmented to include additional scanning and profiling remote sensors and more detailed measurements of the land-atmosphere interface that support high resolution climate modelling. Aerial operations at NSA will link the measurements from Barrow and Oliktok, and unmanned aerial systems will provide additional spatial information around Oliktok.

9.10 MAWS Upgrade to ARM DigiCORA systems - Doug Sisterton

Doug began by giving an overview of the surface measurement configurations at the ARM sites at SGP, NSA, the decommissioned Tropical Western Pacific site, ENA and the ARM mobile facility sites. To standardize all sonde surface measurements and to remove operator error, all ARM sites will be upgraded to the Vaisala MAWS301 automated weather station system. This system provides a simple interface with the DigiCORA and automatically provides surface measurements within a graphical user interface. To date, only the SGP site had been upgraded. The rest of the MAWS were planned to be installed this year and next year.

9.11 Comparison of RS41 and RS92 at SGP - Doug Sisterton

Dual launches at the SGP site were performed over a short period between 3 June and 7 June 2014. 14 daytime and 6 night-time paired RS92-RS41 launches were performed. Preliminary results showed mean temperature differences were within ±0.1°C. There were a few cases with larger differences, typically related to challenging conditions such as the radiosondes emerging from a cloud, or large gradients in the profiles. Mean humidity profiles agreed to within ±2.1% relative humidity. The largest differences were observed at altitudes of 8 to 12 km, with RS92 measuring 1.6 – 2.1% lower relative humidity levels. Mean pressure differences were within ±0.2 hPa in altitudes above 2 km. Near-ground mean difference between RS41 and RS92 was 0.4 hPa. Zonal and meridional wind components were within ±0.05 $m.s^{-1}$, with a standard deviation of differences within 0.26 $m.s^{-1}$. The conclusions were that the RS41 and RS92 radiosondes showed very similar results for all measured quantities. The observed differences between RS41 and RS92 are within the measurement uncertainty for all variables, and similar to those reported from previous campaigns arranged by the UK Met Office and the Czech Hydrometeorological Institute. Other ARM instrumentation measurements are being used to interpret the results. The complete technical report should be completed in the next few months. The ARM programme is planning to move forward with acquisition of the MW41 upgrade, but the transition plan from RS41 to RS92 sondes has not yet been developed. A stockpile of RS92 instruments is still be used.

9.12 CFH Launches at ARM SGP - Martin Stuefer

The ARM SGP site plans to launch one CFH every month. The goal is to provide long-term, high quality and well documented CFH measurements. The CFH launch hardware is funded through Howard Diamond at NOAA. ARM provides mentorship oversight and personnel for the efforts associated with the CFH sonde preparation and launches. They intend to improve and evaluate the procedures for CFH launches at the SGP facility and evaluate CFH launch logistics for use at other ARM sites (i.e. Barrow, Alaska) in the future. The SGP launch procedures for the CFH are following GRUAN Lead Centre recommendations. Launch packages include the CFH instrument from Droplet Measurement Technologies (DMT), and InterMet IMet1 RSB, and a Vaisala RS92 radiosonde. For the RS92 radiosonde, a ground check with the Vaisala GC25 is conducted prior to each launch. Two comparisons of vertical relative humidity profiles from the RS92 and the CFH were shown. Next steps include refining the launch procedures for ARM operators, producing a CFH handbook, producing baseline CFH humidity measurements, defining uncertainties, working towards GRUAN certification, and pushing data from the ARM data management facility to the GRUAN Lead Centre using RSLaunchClient.

9.13 Lidar systems at the US DoE ARM sites - R. K. Newsom

ARM operates a number of lidar systems at its fixed and mobile sites around the globe including micropulse lidars and ceilometers which are considered standard systems and are operated at all sites, and advanced systems which are operated at selected sites and include Doppler lidars, Raman lidars and high spectral resolution lidars. The ARM Doppler lidar measurements include clear-air vertical velocity, winds, turbulence, and aerosol backscatter. The maximum measurement altitude is 10 km but measurements are mostly limited to the atmospheric boundary layer, i.e. < 3km. ARM currently operates, or has operated, 6 Doppler systems at the following sites:

- SGP from 2011 to the present.
- At Darwin from 2010 to 2014 after which it was moved to SGP in 2015.
- The 1st ARM Mobile Facility which was located in Nainital, India, from June 2011 to March 2012, in Cape Cod, USA, from July 2012 to July 2013, and in Manacapuru, Brazil, form January 2014 to the present.
- North Slope of Alaska (NSA), Barrow, from 2014 to the present.
- The 3rd ARM Mobile Facility located at NSA, Oliktok Point, from 2014 to the present.
- Eastern North Atlantic (ENA), Graciosa Island, Azores, from 2014 to the present.

The Doppler lidars are manufactured by Halo Photonics (UK). They operate at a wavelength of 1.5 µm with a pulse width of 150ns providing a vertical resolution of 22.5m. The pulse energy is ~100 µJ and the pulse repetition frequency is 15 kHz. While the maximum measurement range is 10 km, the typical range is ~2-4 km. The velocity precision is ~10 $cm.s^{-1}$. The instrument has a full upper hemispheric scanning capability. The measurements and operation modes include vertical staring and PPI scans once every 15 minutes. Direct measurements of radial velocity and SNR are obtained and derived measurements of attenuated aerosol backscatter, winds and vertical velocity statistics. The ARM Raman lidars are built by John Goldsmith at Sandia Labs, Livermore, USA. The transmitter is a tripled Nd:YAG (Manufacturer: Continuum) laser operating at a wavelength of 355 nm with a pulse energy of ~300 mJ, a pulse repetition frequency of 30 Hz and a pulse with of ~5 ns. The beam diameter is 13 cm and the beam divergence 0.1 mrad. The receiver is a primary telescope of 61 cm f/9.3 diameter. The field of view is 2 mrad for the wide field of view and 0.3 mrad for the narrow field of view. There are 9 detection channels.

The ARM Raman lidars measure water vapour mixing ratio (75 m, 10 sec and 10 minutes), temperature (300 m, 10 and 60 minutes), aerosol backscatter, aerosol extinction, and linear depolarization ratio (75 m, 1 or 2 and 10 minutes) to a maximum altitude of ~30 km. Incomplete overlap limits the measurement accuracy below ~1 km. ARM currently operates 3 Raman systems at SGP (1996 to the present, Darwin from 2010 to 2014 after which it moved to ENA in 2015, and at the 3rd ARM Mobile Facility at North Slope of Alaska (NSA), Oliktok Point, from 2014 to the present.

The ARM high spectral resolution lidars operate at a wavelength of 532 nm with a range of 100 m to 30 km. Their time resolution is 2.5 seconds and their range resolution 7.5 m. They have an autonomous 24/7 mode of operation. The high spectral resolution lidar measurements include aerosol backscatter, aerosol extinction, and aerosol depolarization ratio. Incomplete overlap limits the measurement accuracy below ~2 km. ARM currently operates these instruments at North Slope of Alaska from 2011 to the present; the 2nd ARM Mobile Facility at Steamboat Springs, Colorado, from 2010 to 2011, at Gan Island, Maldives, from 2011 to 2012, and a ship-based site California and Hawaii from 2012-2013; Hyytiälä Finland in 2014, and then again a ship-based site between California and Hawaii in 2015.

9.14 GNSS Analysis for Climate Monitoring and Met Applications at ASI/CGS - Rosa Pacione

Rosa provided an overview of the Matera facility which acts as a geodetic fundamental station due to many overlapping hardware types.

These presentations were followed by an open discussion. Topics of discussion included:

- Marion Maturilli pointed out that while GNSS talks referred to a particular station it is important to acknowledge that at some stations there is more than one GNSS receiver and that exactly which instrument is being referred to must be made clear. June Wang followed up by asking where GRUAN stations have several GNSS receivers whether we want data from all of them or just a selected few. Rosa Pacione felt that it was best to process and include all of them and noted that twin receivers are a good redundancy and check on QA/QC.
- Sodankylä plan to submit GNSS data.

- Belay pointed out that all examples were from European sites and queried how non-European sites might be brought into the network.
- June Wang noted that GRUAN has a GNSS processing centre and asked whether GRUAN wants its GNSS receivers to be part of other network processing. Rosa felt that this was a good idea because it support QA/QC and meta data handling.
- Thierry Leblanc asked whether Belay or Rob would be willing to provide a few hours of lidar data for analysis by using the lidar launch client. For ARM, these data are freely available from the archive but needs to be requested specifically.
- Peter Thorne asked what the probability was of ARM changing its procedures to align with GRUAN. Doug responded that ARM will consider this and would seek site dependent solutions. Clearly recommendations from mentors will be worthy of consideration.
- Holger Vömel asked whether ARM RS41 data have been submitted to the Lead Centre and Donna responded that she would send the data.
- Masatomo Fujiwara highlighted the need for a CFH manual.
- Thierry Leblanc asked Rigel Kivi whether they had submitted the RS92-RS41 dual flight data to the Lead Centre. Thierry asked this as a precursor to how the coordination of RS92-RS41 dual flights was being handled. Rigel responded by saying that he was in favour of submitting the dual flight data to a central database. Holger pointed out that it is important that the data from the dual soundings is submitted properly. The Lead Centre collects all metadata so if a sounding has data from two sondes it must be submitted as such.
- June Wang raised the issue of spatio-temporal match criteria for comparisons of GNSS and satellite-based measurements and whether a kernel should be applied to the radiosonde data before comparison with the space-based measurements. Thierry asked whether applying an averaging kernel makes any difference to the outcome of the intercomparison. Tony Reale pointed out that averaging kernels were not being used routinely.

9.15 Ground-based observations performed by the Italian Met Service Italian Met service - Stefania Vergari

Stefanie began by providing an overview of the organisational structure of the Italian Airforce Meteorological Service. They oversee the operation of 28 airport meteorological offices, 75 manned meteorological stations, 60 automatic weather stations and 6 upper-air stations. The 6 upper-air stations are at Udine Campoformido, Milano, Pratica di mare, Brindisi, Trapani, and Decimomannu. The Pratica di mare site is also a GUAN site. In addition to these 6 sites, they have a station at Vigna di Valle which is also a GAW site which is where experimental soundings are undertaken. These include two ozonesonde flights per month using 1000 gram weather balloons and ECC-6A ozone sensors. The 6 standard operational sites all do twice daily launches at 00Z and 12Z using 600 gram helium-filled balloons (except for Pratica di mare that uses 1000 gram balloons) and the Vaisala MW41 Digicora sounding system. They are using Vaisala RS92 radiosondes until stocks run out and will then switch to RS41 sondes. The stations also run ceilometers, POM sun-sky radiometers, and undertake volcanic ash monitoring.

9.16 News from the metrology community - Andrea Merlone

Andrea gave an update on MeteoMet news, EURAMET news, BIPM news and information contained in the new GUM as it pertains to GRUAN.

MeteoMet is a €10 million project with 300 deliverables incorporating 960 person-months of work. MeteoMet is the largest EURAMET consortium comprising 21 National Institutes of Metrology, 12 universities, 13 research centres, 9 instrument companies, and 10 meteorological agencies. Andrea gave a summary of the development of a traceable portable calibration facility for hygrometers using permeation tubes for in-field use as secondary standard. The AquaVIT 2 intercomparison campaign, with a highly stable humidity source and a traceable calibrated dew point hygrometer, has also provided useful information to support GRUAN activities. The MeteoMet team also undertook metrological activities in the

Arctic in 2014. Andrea also gave an overview of the EDIE (Earth Dynamics Investigation Experiment) and EDDIE (Earth Dynamics Direct Investigation Experiment) calibration facilities and the deployment of EDIE2 in the Himalaya. In 2013 MeteoMet was awarded the EURAMET impact prize.

The MeteoMet2 project started on 1 October 2014 and targets many of the essential climate variables of interest to GRUAN. The first task of MeteoMet2 is to improve the representativeness of radiosonde calibrations under actual measurement conditions. The aim is to develop facilities to calibrate radiosondes under atmospheric conditions including reduced pressure and low temperature. A numerical simulation-based analysis tool will be exploited in designing measurement chambers applicable in operation under reduced pressure and low temperature. A thermodynamic-based humidity generator able to work at sub-atmospheric pressures will be developed. The generated water vapour mole fraction will cover the range from ~0.03 mol/mol to 1.5×10^{-6} mol/mol. Another MeteoMet2 project is ‘Metrology for fast changing quantities in upper air’ whose aim is to provide metrological support for measurements of fast-changing ECVs (temperature, water vapour), where the response time of conventional sensors may be too slow to correctly follow rapid transients being measured. The work aims to extend the characterization of sensors beyond the basic information known when sensors are calibrated under constant conditions. This responds to the needs expressed by WMO to identify radiosonde sensor time constants and the lower bound of the sensors sensitivity. The temperature time lag of the sensor relative to the temperature is considered a possible significant source of systematic error.

In EURAMET news, in 2014 EURAMET started the new Task Group on the Environment that includes Andrea Merlone as the convenor. Under the auspices of EURAMET, an Arctic metrology workshop, was planned for 22 April 2015 at INRiM in Torino, Italy. The goals of the workshop were to address metrology experience and activities in support of the Arctic research, present the expertise of metrology institutes and universities, and plan a joint effort towards the creation of a permanent metrology structure for Arctic research.

Andrea advertised the 2016 MMC (Metrology for Meteorology and Climate) meeting that would take place in Spain and would coincide with the CIMO-TECO meeting.

In BIPM news, Andrea pointed out that there was a new BIPM Task Group on Metrology for Environment. A recommendation had also be been made for the establishment of a joint group from BIPM, CCT, ISTI, GRUAN, and the WMO commissions of CIMO & CCl for temperature uncertainty evaluation.

A summary was given of the revision of the JCGM Guide to the expression of uncertainty in measurement (GUM). Andrea pointed out that the GUM is ambiguous. The definition of uncertainty in the GUM is ‘parameter, associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand’. This is an intrinsically Bayesian view of uncertainty – uncertainty concerns the measurand. However, the definition contrasts with the way in which uncertainty is obtained, essentially frequentist – uncertainty concerns the measurand estimate, and is uncertain. The paradox is that one must **estimate** components to **evaluate** the total uncertainty. Things have now changed so that the GUM and its supplements are now consistent. The changes that will be made/are being made to the GUM include:

- In the revised GUM there will be mostly generic guidance on the construction of coverage intervals.
- Distribution-free coverage intervals, based on Chebyshev or Gauss inequalities, will be given.
- Expanded uncertainty de-emphasized.
- Greater consideration to non-symmetric coverage intervals.
- Greater consideration to multi-variable problems.
- Classification into Type A and Type B evaluations loses its scientific basis, but will be kept (de-emphasized) due to non-scientific considerations.

9.17 Discussion of Issues of the day and impromptu presentations from sites

This section of the meeting was wrapped up with an open discussion that covered the following topics:

- Peter queried why some sites aren't doing the standard humidity chamber tests. He also pointed out that 10 hPa needs to be routinely (i.e. on the majority of occasions) reached by GRUAN sites if we want to be better than GUAN. He also asked by some cites are not using RsLaunchClient correctly. In response to the issue on burst altitude, Belay Demoz stated that they had recently moved to using 600 gram balloons had a lot of stock to go through. Beltsville had purchased a specific humidity chamber test unit. Doug Sisterson answered that the ARM sites were not yet using the standard humidity yet as they had not studied the problem sufficiently deeply to know how much value would be added by having the 100% measurement. Holger Vömel pointed out that the correction can be significant – with help of the SHC a drift of up to 4% has been observed in the RS92 that is attributed to changes in the production . Doug responded that a technical report describing the standard humidity chamber usage was required and that ARM required a peer-reviewed correction or change to methodology. Ruud Dirksen stated that a Technical Document for use of the standard humidity chamber would be available soon.
- Greg Bodeker pointed out that it was good to see the US National Weather Service coming on board. The Beltsville-Sterling combination could be a "super-site" for GRUAN give the wide range of instrumentation in operation in the DC Metropolitan area. Jim Fitzgibbon suggested that the other possibility was for the NWS to support the Lead Centre directly and asked what gap they might fill. The follow-up suggestion that Jim made was that NWS could do field support, training and could document processes through videos. One internal suggestion was to transition the upper-air soundings to a different facility. Tom Gardiner stated that help with developing documentation could be useful for translating GRUAN documents to the GUAN community. Greg Bodeker also pointed out that developing documentation so that it is appropriate for WIGOS would also be helpful.
- Belay Demoz raised that in the context of GRUAN-GUAN connections it would be advantageous to see another manufacturer qualified.
- Tim Oakley made the point that a number of stations are both GUAN and GRUAN sites and queried what GRUAN does do to change the GUAN stations. He highlighted that if there is no propagation of value from GRUAN to GUAN sites that it will be difficult to convince other sites of GRUAN's value. In response, Martial Haeffelin pointed out that the GRUAN uncertainty corrections developed for the MODEM sondes would directly benefit to the GUAN network. Peter Thorne responded that this is where GRUAN stations need to start by reporting BUFR and then get GUAN sites to do the same.
- Rolf Philipona pointed out that Payerne is a GUAN and GRUAN site. ECMWF sends feedback reports every month to highlight if something is incorrect. The fact that Payerne is now a GRUAN site has forced an improvement in the quality of the measurements. Rolf suggested that we should look at other GUAN sites that might want to become GRUAN sites. Greg Bodeker asked what the incentive was to move to BUFR. Bertrand Calpini reminded attendees that Payerne existed before GRUAN started. He saw a huge benefit in GUAN-GRUAN collaboration. He also stated that it would be good to have other solutions from other providers. In regards to what GRUAN brings to GUAN he said that GRUAN works on a better foundation to provide better quality data. While it was difficult to qualify it, he is a strong supporter.
- Dian Seidel queried whether there had ever been a meeting of GUAN site representatives and wondered whether there would be any value in having a joint GRUAN-GUAN site representatives meeting.
- Greg Bodeker summarized some of the dangers that GRUAN faces. If GUAN sites did what was in their operational manuals GRUAN wouldn't be necessary, but because GUAN sites are not ejected from the network if they do not follow WMO mandated protocols, there is little incentive to undertake the additional work required to meet GUAN standards. We need to ensure that some-

thing similar does not happen to GRUAN. Sites not meeting the required standards must be removed from the network.

- Peter Thorne asked how we can change the sites to be part of GRUAN for the other 51 weeks of the year i.e. outside of ICMs. He asked whether sites feel we are doing enough to support the transition to a new radiosonde (not necessarily RS41) and pointed out that GRUAN sites need to take ownership of this. Belay Demoz responded that from the sites perspective there are costs involved in managing the change away from RS92. Greg Bodeker highlighted that the radiosonde transition challenge can bring the GRUAN community together. GRUAN needs to produce a synthesis document that contains all of the transition studies that have been done and in doing so would force sites to work together. All of the RS92-other transition knowledge generated by the GRUAN community needs to be captured in one document. Fabio Madonna stated that the transition is completely in the hands of the sites. Bertrand Calpini defended getting the best measurement, no matter the vendor. Peter Thorne agreed that it was important that we give sites more than one option. It is not predetermined that the move will be towards RS41. It is also important for GRUAN to provide guidance back to GCOS on the transition. Peter Thorne pointed out that GRUAN is able to manage the RS92 transition because the sites have a wide range of ancillary measurements that can inform that transition. Tom Gardiner clarified that knowledge of uncertainties is the way to establish that two measurements are comparable. Every site needs to go through a management and change process. There should be a central repository that holds the results of these intercomparisons. Doug Sisterson stated that it would be wonderful if we knew the entire expression of error in a radiosonde. We can calibrate, etc., but the climate at each site has environmental factor(s) that make the reproducibility difficult. If you knew all the uncertainties, you could use whatever radiosonde you want. Therefore, to some extent, the RS92 transition is a site-dependent problem. Peter Thorne pointed out that at ICM-6 we had an action on the Task Team for radiosondes to come up with a transition plan.

9.18 Discussion of potential new sites in GRUAN including brief reports by nominated shepherds on progress – facilitated by Greg Bodeker

All information related to new sites coming into GRUAN is available at http://gruan.wikidot.com/newsite. Key points arising from this discussion included:

- June Wang said that the site in China want to wait on radiosonde selection, and will visit Lindenberg.
- Bolivia: Greg Bodeker discussed the crowd funded RS92 programme. The Lead Centre will test data in GRUAN pipeline and see how that goes.
- Cuba: Peter Thorne suggested that with a change in US-Cuba relations this may open up possibilities and that it may therefore be worth inviting Juan Carlos to the next ICM. Dian Seidel wondered what the US National Weather Service view to Cuba might be and whether a NOAA/NWS engagement with Cuba might be a good thing to try. Jim Fitzgibbon offered to take this forward.
- Australia: Alice Springs might be good site since it is also a BSRN site.
- South Africa: Belay Demoz said that there was an MOU in place to continue the SHADOZ operations.
- Senegal: Belay Demoz reported that they are doing MODEM launches and are measuring surface ozone. We should Seydi to next ICM.
- Vietnam: Masatomo Fujiwara reported that some GRUAN docs have been translated into Vietnamese and was waiting on a response from his collaborator in Vietnam. A visit to the site may be necessary.
- Russia: Kalev Rannat offered to approach Alexander Kats to get the ball rolling.
- Canada: Need to invite Jim Drummond to next ICM.
- For Chile and Argentina the problem is that the radiosondes are too far away from the instrumen-

tation.

- Bertrand Calpini suggested that a GRUAN site in Nairobi was not worth pursuing.
- Singapore: Greg Bodeker to go in person and show them the value of their sonde data. Sondes not launched from Changi airport. Launched from National Environment Agency (10 km away)
- Antarctica: We need to communicate via Rigel regarding a GRUAN site in Marambio.
- Tenerife: Xavier Calbet offered to travel there to speak with them.
- Dian Seidel queried whether we should be trying to get all of these new sites on board if we can't engage with the sites we already have. Greg Bodeker responded that we have to try. Eventually all of the site reps won't come to ICMs once we have 30-40 sites. No better option yet other than a shotgun approach.

10. Site visit

Participants were welcomed to the Potenza facility of CNR by Dr Vincenzo Lapenna, director of the IMAA facility. He outlined how this was the largest facility in the thematic area within Italy. They are involved in many aspects of earth observation. He highlighted strong activity within the European domain and work with space-based observations. The centre has a staff of 80 plus PhDs and postdocs plus several international visiting scientists. The institute aims to further strengthen the CIAO facility.

Gelsomina Pappalardo gave an overview of the CIAO facility and its role within both European and global communities. CIAO is now a well-established ground-based remote-sensing facility. Since 2000 aerosols, water vapour and cloud processes have been the focus. It has 6 researchers, 3 technicians, 6 PhD students and a postdoc. All data are provided to the research community. It has been built step by step rather than from a large start-up grant. It has increasingly become part of European research infrastructure to carry out monitoring and research. The challenge is in gaining maximum science value from past, current and future observations at the facility.

The CIAO facility is involved in efforts to develop and characterise instruments including quality assurance. There is also interest in exploring synergies of instruments at the facility. The facility contributes to GAW (GALION), EARLINET, AERONET and Cloudnet. It is involved in several EU projects including leadership roles. It also has a leading role in informing the European ESFRI strategy.

The ACTRIS project has been led by CNR and aims to provide long-term monitoring of clouds, aerosols and trace gases within Europe that is coordinated. It has centralised data collection and aims to train and sustain capability. ACTRIS aims to bring together CLOUDNET, EARLINET, APRIORI, CREATE and EUSSAR to combine existing measurements to realise synergies and improve application areas such as climate change, radiative forcing etc.. ACRTIS aim to bring together rather than replace existing networks, improve observation strategies, standardize data and metadata and collate and integrate the results to provide added value to both participants and users. Access to sites, training and capability are key. In the first stage this was limited to Europe, but now it will be possible for most global actors to access the training programme and facilities.

ACTRIS 2 follow-on starts in May 2015 and runs through 2019. The programme funds the infrastructure aspects but not the measurements per se. This includes more access for global participants to participate in calibration activities. Efforts will be made to cooperate on AERONET retrievals. The capabilities are spread across most of Europe. There are funds available for scientists to visit all parts of the infrastructure. Innovation, training and outreach have increased focus.

The long-term strategy is to work towards a sustainable research infrastructure for Europe. This includes the ESFRI preparatory phase project which shall start in 2017 and would assure a sustainable infrastructure of observing capabilities. The active phase of ESFRI shall begin in 2020. A lot of work is required to break down barriers that have been built over time partly as a result of past funding decisions. The vision is for a combined and sustainable infrastructure to monitor in the long-term the environment through at least 2040. The current infrastructure remains somewhat fractured with many aspects being dependent upon short-term projects with finite funding support.

Giuseppe D'Amico gave an overview of the single calculus chain for EARLINET – the lidar aerosol network. The network consists of 27 active stations running lidars that are all distinct from one another. This requires distinct analysis on an instrument-by-instrument basis but this analysis needs to yield to homogeneous data. All data are submitted to a central repository (level 0) that are then pre-processed to be consistent across the network (level 1) and then analysed in a consistent manner (level 2). There is then a web-server that users can use to interrogate the database. The system has in-built flexibility and expandability. It is relatively easy, in principal, to add new instruments. There is a total of almost 1600 measurements available to date. There is work ongoing to extend the analysis capabilities with new products such as particle linear depolarization. This will enable improved understanding of aerosol characteristics permitting e.g. differentiation of dust from biomass burning. Cloud masking remains the critical challenge to interpret aerosol lidar profiles. Several potential avenues are under active consideration.

Lucia Mona outlined activities related to satellite validation and model evaluation. She pointed out that redundancy of instrument capabilities at CIAO provides confidence in the reality of the ground-based observational basis. A focus has been on characterisation of CALIPSO measurements. The focus has been on temperature, humidity and aerosols. Some COSMIC programme efforts have been made as well. There is reasonable concordance in aerosol optical depth from CALIPSO and EARLINET, although with spread when the proportion of aerosols in the free troposphere is high. EARLINET has some number of 'clusters' of stations within relatively small domains that allow some determination of cross-validation. New work is investigating level 3 data products from CALIPSO for climate studies using long-term comparisons with several EARLINET stations that have long-term records. This has highlighted some limitations within the current CALIPSO level 3 product, particularly near coasts where types that can occur in reality are restricted.

Nico Cimini presented an overview of SatClop which is concerned with satellite remote sensing of cloud properties including precipitation. SatClop uses multi-spectral techniques across the visible, infra-red and microwave domains. Several case studies were shown and validated against in-situ, radar and other observations. They can also detect Saharan Air Layer dust events. A product is produced that estimates total irradiance that is of use for example in solar photo-voltaics. This has been validated against GAW records. Precipitation can be estimated from microwave measurements. The importance of validation of new and novel satellite products using ground-based reference quality data was stressed.

Antony Giles outlined synoptic soundings in Italy and the migration to the RS41. Within Italy, several organizations undertake radiosonde measurement. All have been using RS92 and sounding systems so the effect of the RS41 change is being felt by multiple organisations within Italy. Launches will be made with both manual and autosonde launchers.

11. GRUAN management and communication

11.1 The GRUAN launch event – Greg Bodeker

Greg Bodeker gave a summary of the planned GRUAN launch event to take place at WMO Congress. The event was originally envisaged as a 2.5 hour event that would celebrate GRUAN's successes to date and bring GRUAN to the attention of the WMO permanent representatives who will be attending the 2015 WMO Congress. Considerable preparatory work was done starting March 2014. Greg Bodeker met with Wenjian Zhang in Geneva in May 2014 to discuss the event. Stephan Bojinski did a lot of work across various WMO agencies. It was also discussed at the last two AOPC meetings. There was no feedback from GCOS Secretariat until a telecon on 16 February 2015 which resulted in significant changes to the event. This will be a 1 hour event that will take place during the lunch break 12:45 to 13:45 on 2 June 2015 at WMO Congress. GCOS Secretariat will invite the Permanent Representative from Germany to run the event. This will no longer be cast as a 'launch event'. The Lead Centre is expected to attend the event. We will send in advance any material to be handed out at the side event. This will include the GRUAN brochure, the 2 page GRUAN flyer and some reprints of the BAMS paper. Unfortunately the GRUAN co-chairs that were asked to organize the event were not invited as they are not associated with a NMHS and only national delegates are invited. Carolin Richter will introduce GRUAN. Certificates will be handed out by the Lead Centre.

A discussion followed on the events leading up to ICM-7. Roger Atkinson offered to follow up on the communication between GCOS, GRUAN and WMO. Roger also remarked that the term 'launch event' may be misleading as from WMO perspective the launch of a NRT GRUAN data stream would make GRUAN very visible and warrant a launch event. Geir Braathen remarked that it should be possible to have parallel – NRT and off-line – data streams.

11.2 Discussion on the GRUAN/GAW collaboration – Geir Braathen

Geir gave a presentation on the links between GRUAN and GAW. GAW observes six categories of parameters, viz. stratospheric ozone (total, Umkehr, ozonesondes), greenhouse gases (CO_2, CH_4, N_2O), reactive gases (O_3, CO, VOCs, NO_x, SO_2 etc.), aerosols, total atmospheric deposition (formerly precipitation chemistry), and solar UV radiation. Geir brought to the attention of the audience GAW Report no. 201 on standard operating procedures for ozonesondes. He then went on to talk about how water vapour is the 'forgotten' molecule. Among all the compounds relevant for atmospheric chemistry, water vapour has been neglected. The GAW Programme has the responsibility for Atmospheric Chemistry in WIGOS. While in the OSCAR database there is a line for H_2O (intended as a chemical species relevant for atmospheric chemistry), this line is essentially empty and so we need to determine the requirements for water vapour. The Scientific Steering Committee for GAW (EPAC SSC) has decided to adopt water vapour as a GAW parameter i.e. water vapour as a chemical species relevant for atmospheric chemistry and as a greenhouse gas. The SSC also decided to establish a Task Team to review the current situation (capabilities) with respect to water vapour measurements and to determine the requirements for such observations. Regarding water vapour as a greenhouse gas, the total greenhouse effect is 155 $W.m^{-2}$ and water vapour is responsible for about 60% of the total greenhouse effect. Water vapour does not control the Earth's temperature, but is instead controlled by the temperature. The water vapour feedback doubles the warming effect of an increase in CO_2. If we add enough CO_2 to cause an increase of 1°C in the global mean temperature, the water vapour feedback will add another 1°C. Stratospheric water vapour increased between 1980 and 2000, but decreased by about 10% from 2000 to 2009. This decrease in water vapour acted to slow the rate of increase in global surface temperature by 25% over 2000-2009. Regarding water vapour as a chemical compound, it is a major source of HO_x in "clean" (hydrocarbon poor) air this makes the ozone lifetime in the marine boundary layer dependent on absolute concentrations of water vapour (i.e. temperature) and overhead ozone. Geir also gave a brief overview of the role of water vapour in ozone depletion. Heterogeneous chemistry on the ice particles in polar stratospheric clouds (PSCs) drive ozone depletion. The critical temperature for formation of Type 1 PSCs depends on the concentration of water vapour and HNO_3. More water vapour in the stratosphere will lead to more PSCs and more ozone depletion as long as there are significant ozone depleting substance abundances in the stratosphere. Finally Geir highlighted the multiple interactions between the GAW, GRUAN, EARLINET, SHADOZ, TCCON and NDACC networks. Relationships between networks and GAW are established through letters of agreement. Work on formalization if a GAW-GRUAN cooperation is needed and GAW will take the initiative on this. Dian Seidel remarked that a link with GAW would position GRUAN better in WMO. Andrea Merlone remarked that GAW has a strong link with atmospheric chemistry and suggested to connect with the temperature community which also deals with sea temperature – which is linked to water vapour through warming effects. Holger Vömel remarked that GRUAN ozonesonde activities are already informally linked to GAW activities in Jülich.

11.3 Discussion around whether WG members' terms should be fixed terms or not – Peter Thorne

Peter Thorne pointed out at the start of the discussion that no matter what decisions were made now he would not be able to take changes in the terms of reference for the Working Group to the AOPC meeting directly following ICM-7. The background to the discussion was that concerns had been raised that lack of rotation of Working Group membership might cause stagnation. Geir Braathen illustrated that, in comparison in GAW, the scientific advisory group and scientific steering committee members are elected for 4 year terms with a maximum of 8 years. This excludes ex-officio members. Turnover is considered healthy. Tom Gardiner considered that there is a lot of activity in the Working Group, and that because there was no stagnation, there was no need to rotate now. Dian Seidel remarked that communication with AOPC should not be leading for GRUAN changes. Further, if Working Group members rotate out, they may still act as ambassadors for GRUAN in their fields. She supports a Working Group refresh. Holger Vömel, commenting as the ex-head of the GRUAN Lead Centre, suggested that the Working Group is too large to be effective. Greg Bodeker was at first opposed to fixed terms but now subscribes to Dian's view. Geir Braathen pointed out that it took GAW 25 years to establish their fixed terms of reference. NDACC has a 3 year limit on terms but with no limit to the number of renewals. Thierry LeBlanc asked whether there was a moment to change the membership to which Peter Thorne replied that the current construction works reasonably. Whit it could be better it is not fundamentally wrong. Greg Bodeker suggested that rather than the current 23 members (excluding ex-officio members and the Lead Centre) that this could be restricted to 18+2 (TT co-chairs, site representatives and co-chairs). He proposed to see at ICMs (yearly) who has been on the Working Group for a very long time and evaluate. Roger Atkinson remarked that this is an extraordinarily large Working Group, that the usual size for a Working Group is ~12 and that we should aim for something smaller. Richard Querel wondered whether both co-chairs of all task teams should be on the Working Group and one should be sufficient. Thierry Leblanc responded that task teams can have a very large number of tasks that cannot be overseen by a single chairperson. Peter Thorne pointed out that rotating off will have consequences e.g. attendance at ICMs. Dian Seidel also highlight that rotation needs to happen in such a way that institutional understanding is not lost. The decision was made to continue this discussion in the period between ICM-7 and ICM-8 and to revisit the issue at ICM-8.

11.4 Discussion of GCOS ECV tables and GRUAN – Tim Oakley

Tim began by pointed out that GCOS must submit a Third Report to Subsidiary Body for Scientific and Technical Advice (SBSTA) of the UNFCCC in 2015, and develop a new Implementation Plan in 2016, with a draft of the latter encouraged to be provided one year before. He then gave an overview of the roadmap for the development of the new GCOS Implementation Plan. A status report on the global observing system for climate and an assessment of the adequacy of the global observing system for climate against ECVs would inform the new Implementation Plan. Issues addressed in the subsequent discussion included:

- Greg Bodeker asked what GRUAN can do to be included in GCOS Implementation Plan. Tim Oakley responded that we must take the initiative and that doing so would create visibility in GCOS.
- Roger Atkinson pointed out that: 1) It is important for GRUAN to be well connected to WMO. A challenge exists due to participation of different organisations that are not per se WMO linked. 2) The WIGOS framework important and GRUAN should be in the WIGOS framework. 3) The connection with satellites is important. 4) The CIMO connection to surface-based remote sensing is very important and WMO considers surface-based remote sensing extremely important for the future. Tony Reale responded that Rogers' message should be communicated at a high level to GRUAN participating institutions so that it will reach GRUAN scientists.
- Thierry LeBlanc mentioned that the need for remote sensing in GRUAN can be similarly implemented as was done for the radiosondes.

11.5 GRUAN website and communication tools – Michael Sommer and Greg Bodeker

GRUAN currently uses a wide range of communication tools including the web site, the blog, email distribution lists, Google docs, a wiki, and site reports. Some of these are available externally but some are only accessible to invited participants (such as the GRUAN wiki). Email distribution lists are used primarily for communication in and between GRUAN groups including the Working Group, Task Teams, the Lead Centre, and the ICM organisation team. This requires Task Team co-chairs to inform the Lead Centre of any change in membership. Google docs is used to manage the GRUAN Master Action Item List. In summary, while there is an array of tools available, it may be that we are not always using the best tool for the job. It was pointed out that most of the content for the communication comes from the Lead Centre and from the Working Group co-chairs. There are been few contributions by community to the GRUAN web site and blog. It is intended that more material will be sourced from the community in future. The Lead Centre requests all teams and sites to give a regular contribution to the GRUAN web site or blog e.g. a short (one to two pages) article about a theme relevant to GRUAN such as any campaigns, experiments, projects, publications, analyses performed, side meetings etc.. Future plans include establishing a new version of the GRUAN website including a refreshed look and feel, author/user management, and merging some of our communication tools into one facility. Proposed future tools include access to the GRUAN meta-database that would provide an easy view into the GRUAN meta-data. Sites would be able to manage/change non-critical parts of meta-database. Implementation of project management and/or a task tracker system for all of GRUAN that would allow an overview of GRUAN activities and would allow bug reports, change requests, timelines etc.. Any other ideas that people may have should be communicated to the Lead Centre.

Greg Bodeker agreed that the number of tools should be reduced to the extent possible. He also floated the idea of a quarterly GRUAN newsletter. Regarding thinking of ways to attract people to the website, sending the quarterly is usually not the way. Dian Seidel suggested that an editor should be appointed and that the editor should contact people actively to contribute to a newsletter. Andrea Merlone felt that the current website was too much and that it should be moved out from DWD should be changed to being clean and modern. Richard Querel requested that the URL handling should be improved to be able to send links to people. Peter Thorne said that dynamic links will be very important (even Twitter).

11.6 The GRUAN work plan for 2015/16 – Peter Thorne

The meeting closed with a review of the work plan for 2015/2016. Agreed actions are summarized in Appendix C: 2015/2016 Action Items.

References

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Appendix A: Acronyms

3G	GNSS-RO/GRUAN/GSICS
AERI	Atmospheric Emitted Radiance Interferometer
CNR	Consiglio Nazionale delle Ricerche – Italian National Research Council
DOI	Digital Object Identifier
ECMWF	European Centre for Medium-Range Weather Forecasts
FTIR	Fourier Transform InfraRed
GCOS	Global Climate Observing System
GFZ	GeoForschungsZentrum
GRUAN	GCOS Reference Upper-Air Network
GSICS	Global Space-based Inter-calibration System
GTS	Global Telecommunication System
IASI	Infrared Atmospheric Sounding Interferometer
IPCC	Intergovernmental Panel on Climate Change
KIT	Karlsruhe Institute of Technology
MLS	Microwave Limb Sounder
NDACC	Network for the Detection of Atmospheric Composition Change
NIST	National Institute of Standards and Technology
NMHS	National Meteorological and Hydrometeorological Services
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
NWP	Numerical Weather Prediction
OSCAR	Observing Systems Capability Analysis and Review
OSSE	Observing System Simulation Experiment
PRR	Pure-Rotational Raman
SASBE	Site Atmospheric State Best Estimate
SHADOZ	Southern Hemisphere ADditional OZonesondes
TCLW	Total Cloud Liquid Water
TCWV	Total Column Water Vapour
WIGOS	WMO Integrated Global Observing System
WIS	WMO Information System
ZTD	Zenith Total Delay

Appendix B: Achievements of ICM-6 action items

Green Completed
Orange Partially completed
Red Not completed

Action	Owner	Due	Status
GRUAN report synthesizing the four white papers developed through the GRUAN network expansion workshop. Circulation of 1st draft to author team	Greg Bodeker	April 2014	Report is now published. Action closed
Co-chairs to provide desired metrics on data usage / impact metrics to extent possible	WG Chairs	May 2014	Delivered to Lead Centre. Action closed
Responses to requests from sites for letters from WG-GRUAN / GCOS to be actioned. Letters to be drafted and sent. Letters requested in site reports or at ICM-6	WG-GRUAN chairs, Lead Centre, GCOS Secretariat	May 2014	Only Potenza followed up. Letter drafted twice but never sent from secretariat
A document detailing the operational challenges related to multi-payload soundings submitted either to peer reviewed literature (first choice) or to WG-GRUAN for review as a GRUAN report	TT radiosondes	June 2014	In progress (a draft ready for being circulated within an expanded co-author list, 2 Sep 2014). Date changed from 30-June-14 to 31-Dec-14
Prepare plan for GRUAN launch activity at WMO congress and report plan to GRUAN community at ICM-7	WG-GRUAN, Lead Centre, Lars Peter Riishojgaard	June 2014	In progress. Needs a further redraft still. Greg is lead
Define necessary steps to undertake transition from RS-92 to RS-41.	TT-Sites, Lead Centre, HMEI, WIGOS project officer, GCOS Implementation Manager	June 2014	In progress. Talk scheduled at ICM-7
TT and WG terms of reference to be revised by chairs and submitted to AOPC for approval to incl. inter-alia discussion around scientific coordinator role	TT and WG Chairs	June 2014	Done, adopted and posted. Action closed
To close the feedback loop for instrument and processing performance, TT sites to summarize how	TT sites	June 2014	Done. Action closed

they wish to receive near real-time feedback.			
Establish closer working ties between tropical GRUAN sites and SHADOZ sites - short report on how to establish greater linkages	Greg Bodeker	June 2014	Done. Action closed.
Prepare public outreach material. This includes updating the GRUAN brochure	Greg Bodeker	Jun 2014	Brochure draft under review. Emma Scarlet will have this finished in the next two weeks.
Submitted BAMS article on the next steps in GRUAN including network expansion and some highlights. Greg Bodeker to contact BAMS editor. Paper to be submitted to ensure publication in time for WMO congress	WG-GRUAN, Greg Bodeker	Sept 2014	Paper accepted for publication. Action closed.
TD omnibus of all things RS-92. Lead Centre to send everything to Bodeker Scientific for collation and editing. Gaps to be identified and Lead Centre will try to address the gaps. Greg Bodeker and Peter Thorne to determine how to accommodate updates.	Greg Bodeker, Lead Centre	Sept 2014	Superseded. Discussions with Lead Centre led to proposal to instead have a radiosonde omnibus with per instrument technical annexes. To be discussed at ICM-7. How to accommodate updates has been addressed and published as TN#2
Technical documentation completed for frostpoint hygrometer measurements	Lead Centre, Task Team radiosondes	Sept 2014	Partially met. Talk will update on progress and work still required. Propose that with Holger's move this be transferred to sole responsibility of TT radiosondes
A short GRUAN report detailing the process implemented to provide feedback of observation minus background fields to the GRUAN Lead Centre	David Tan and Lead Centre	Oct 2014	Well-advanced. There has been a lot of (technical) work at ECMWF to prepare and serve the feedback data via a user-friendly web-interface (with batch access also possible, e.g. via python scripts). In Q1/Q2 of 2015 I would like Lead Centre to start experimenting with the accessing (pulling) the feedback. Will they have resources to do so? There will also be a learning curve for how to analyse and interpret the results - will complement Gaia-clim. Request reset the due date to Jun 2015
Sites reporting either TEMP or not reporting on the GTS / WIS to work with Lead Centre, WIGOS and HMEI to ensure GRUAN sonde launches are sent as 2s resolution BUFR. Briefly report progress and issues to ICM-7. Data flowing through WIS	Lead Centre, TT sites, WIGOS project office, GCOS Implementation Manager, HMEI	Oct 2014	Some progress. Details of how to start this process have been shared with LC.

as BUFR high vertical resolution for as many sites as possible.			
An assessment of the advantages and disadvantages of manual vs. autosonde launches written up and submitted to the peer reviewed literature	Task Team Radiosondes	Nov 2014	Open
Each site to produce a proposal of how they will document by photos seasonal and long term site changes (regular e.g. quarterly from stated locations / daily webcam shots etc. as appropriate to their specific case, and 'on change'). Proposals collated and documented for WG-GRUAN review and feedback	Task Team Sites	Nov 2014	Generic proposal received from TT sites chairs. Specific plans still required from each site?
Technical documentation for GRUAN Lidar stream (Lidar Guide) submitted for review by WG-GRUAN	Task Team Ancillary Measurements	Dec 2014	In progress
Microwave radiometer technical Documentation (Microwave Guide) submitted for review by WG-GRUAN	Task Team Ancillary Measurements	Dec 2014	In progress. Task under GAIA-CLIM WP2. Reset date to 2016
FTIR technical documentation (FTIR Guide) submitted for review by WG-GRUAN	Task Team Ancillary Measurements	Dec 2014	In progress. Task under GAIA-CLIM WP2. Reset date to 2016
Manuscript(s) detailing operational considerations for controlled descents for frostpoint hygrometers submitted to a journal or detailed in a GRUAN Report	Task Team radiosondes	Dec 2014	In progress. Change date to June 2015
Manuscript describing the derivation of uncertainty estimates for GNSS-PW measurements submitted to a peer reviewed journal	Task Team GNSS-PW	Dec 2014	In progress. Funding secured to complete this in 2015. Move to Sept 2015
In collaboration with partner networks, assess the relevance and tractability of the full suite of remaining GRUAN target variables defined in GCOS112 in the context of measurement capabilities and measurement programmes underway in partner networks. GRUAN	WG-GRUAN Chairs, Lead Centre, TT ancillary measurements, TT site representatives	Dec 2014	Not done. Resolving other actions more important.

report identifying potential target data streams and partners			
Develop frostpoint hygrometer data products. Guidance needs to account for operation of CFH, NOAA FPH. Paper submitted to a peer reviewed journal.	Lead Centre, Task Team Radiosondes	Dec 2014	Partially met. Independent ground-check developed for CFH but final analysis and write up still pending. Move to Sept 2015. With Holger's move suggest this comes under sole auspices TT radiosondes
Develop a GRUAN ozonesonde data product in consultation with NDACC and GAW. Completed technical documents	Greg Bodeker, Lead Centre.	Jan 2015	Jacqui Witte will be working with Greg Bodeker in April and May to get this done.
Lead Centre to report on data usage / impact metrics (following recommendations from #2) to extent possible	Lead Centre	Mar 2015	LC has started to compile a list of GRUAN-related publications/presentations. This will be included as an appendix to this report.
Revise the RS-92 data stream based upon feedback received - revised version 3 release including qc flags vectors and data in different vectors (good, questionable, missing), including implementation of performance feedback.	Lead Centre, Task Team Radiosondes	Mar 2015	Partially met. Current v3 candidate will be discussed in detail at ICM-7
Perform demonstration study of SASBE at time of satellite overpass based on a realistic set of assumptions about the availability and colocation of sondes and ancillary measurements. Focus is on temperature and water vapour	Task Team ancillary measurements	Mar 2015	In progress
Instigate a user review group to meet on a biennial basis. User review group terms of reference drafted and agreed to by WG-GRUAN for subsequent consideration by AOPC	WG chairs	Mar 15	AOPC requested this be stayed so it has been closed as an item of business.
Develop GRUAN data product and processing stream for Modem radiosondes. First draft of technical document describing processing streams for all Modem radiosondes	CNRS, Lead Centre, TT radiosondes	Mar 15	In progress. See later talk
Determine the status of BSRN and reengage with GRUAN. Report back to WG on BSRN status and whether their measurements are reference	Richard Querel	Mar 15	There was an email exchange but nothing substantive resulted. One action arising from it through conversation with Tom is to make a detailed comparison of the current networks to

quality and if not what we would need to do extra. Invite someone to ICM-7 from BSRN. GRUAN representation at BSRN meeting in September			better understand them. i.e. Some use identical hardware and processing pipelines (TCCON), whereas NDACC is a mixed bag relative to that. Knowing more about how the networks operate, standardise, etc., will help GRUAN interact with them.
Develop an advanced 'template document' for non-RS92 radiosondes for later distribution to specific users	Lead Centre, Task Team radiosondes	Mar 15	Superseded by the suggestion for radiosonde omnibus with per instrument technical annexes. Retired.
Develop a GRUAN GNSS-PW product. Technical documentation completed for GNSS-PW measurements (GNSS-PW Guide)	Task Team GNSS-PW	Mar 15	In progress
Pedagogical paper on appropriate propagation of uncertainties and generic code – paper draft available for comment	Greg Bodeker	Mar 15	Paper submitted to AMT. Action closed
Reports from WG and GRUAN community members on efforts to further contributory site set. Single page write ups for each site by selected GRUAN leads at ICM-7 (list of sites and contact points in main report) and also reports on phone calls	WG-GRUAN, Lead Centre, ICM-6 participants	Mar 15	Partially met pending receipt of written reports and their presentation

Appendix C: 2015/2016 Action Items

	Action	Owner	Due
High priority actions			
1	Technical note outlining the process that will be undertaken to certify a new program at a site with an existing certified measurement program	WG Chairs, TT Chairs, Lead Centre	June 2015
2	Produce a Technical Note highlighting the steps that must be achieved for a GRUAN product to be accepted ('certified') and released. WG to review criteria for acceptance	WG chairs, TT chairs, Lead Centre, Holger Vömel	Aug 2015
3	All sites with capability to report BUFR over GTS in NRT. Advice and tech. support to be provided by LC / WMO / GCOS on a site by site basis to all certified and candidate sites not currently reporting BUFR to attempt to enable. In first instance LC to ascertain status for each site as to why not reporting BUFR to GTS and advise Tim Oakley and Roger Atkinson.	Lead Centre, GCOS, WMO, TT sites	Sept 2015 for initial reports for each site to Tim and Roger ICM-8 for all sites with capability to be reporting BUFR
4	Define strategy and necessary steps to undertake transition from RS-92 to another sonde model. Produce GRUAN report on strategy and rationale including inter-alia: – Sharing the burden – Role of ancillary measurements – Plans for parallel measurements – Ensuring competition in marketplace	Lead Centre, TT radiosondes, TT sites, WMO, GCOS	Oct 2015
5	An assessment of the advantages and disadvantages of manual vs. autosonde launches written up and submitted to the peer reviewed literature	TT radiosondes	March 2016
6	Lead Centre to work with sites not attaining regularly 10hPa to understand why and help improve situation. Short report from each affected site at ICM-8	Lead Centre, TT sites	April 2016
Ongoing actions			
7	Please send relevant funding calls to the science coordinators so that they can disseminate to relevant parties and cajole to get GRUAN partners cooperating in proposals	Science coordinators	
8	Produce a quarterly 2-page newsletter for dissemination to the community email list to be sent by Lead Centre	Greg Bodeker, Emma Scarlet, Science Coordinators	Quarterly
Time-bound actions			

9	Finalize and publish the GRUAN brochure	Greg Bodeker	April 2015
10	Letter of support for closer collaboration between CNR and Italian Met Service in support of Potenza site and broader Italian UA program	WG Chairs, Potenza, Secretariat	May 2015
11	A short GRUAN report detailing the process implemented to provide feedback of observation minus background fields to the GRUAN Lead Centre	David Tan, Lead Centre	June 2015
12	GRUAN information event at WMO congress to include presentations from PRs and handing of certificates.	Lead Centre, GCOS secretariat, with input from WG Chairs	June 2015
13	Prepare and disseminate promotional video for GRUAN. Site reps to send segments to Greg.	Greg Bodeker, Lead Centre, TT sites	Aug 2015
14	A document detailing the operational challenges related to multi-payload soundings submitted either to peer reviewed literature (first choice) or to WG-GRUAN for review as a GRUAN report	TT radiosondes, NOAA NWS, TT sites	Sept 2015
15	Manuscript describing the derivation of uncertainty estimates for GNSS-PW measurements submitted to a peer reviewed journal	TT GNSS-PW	Sept 2015
16	Extend trend sensitivity studies to stratospheric water vapour	TT Scheduling	Sept 2015
17	Each site to produce first version of photos to document seasonal and long term site changes (regular e.g. semi-annually from stated locations / daily webcam shots etc. as appropriate to their specific case, and 'on change'). Uploaded to GRUAN website. LC to instigate mechanism to remind sites.	TT Sites, Lead Centre	Nov 2015
18	Develop first draft of GRUAN radiosonde generic technical document omnibus	Lead Centre, Task Team Radiosondes, Greg Bodeker, but also include some non-instrument experts, WMO ET can review	Nov 2015
19	Develop GRUAN data product and processing stream for Modem radiosondes. First draft of technical document describing processing streams for all Modem radiosondes	CNRS, Lead Centre, TT radiosondes	Nov 2015
20	Lead Centre and US National Weather Service Sterling facility to meet in person to discuss collaboration and advise Working Group	Lead Centre, NWS, broader NOAA contingent	Nov 2015
21	Technical Note on the appropriate techniques for manufacturer independent ground checks using the SHC. Paper submitted to peer review documenting scientific rationale	Lead Centre	Dec 2015
22	Technical documentation for GRUAN lidar stream (lidar Guide) submitted for review by WG-GRUAN	TT Ancillary Measurements	Dec 2015

23	Develop frostpoint hygrometer GRUAN data products. Guidance needs to account for operation of CFH, NOAA FPH. Paper submitted to a peer reviewed journal.	TT radiosondes	Dec 2015
24	Develop a GRUAN GNSS-PW product. Technical documentation completed for GNSSPW measurements (GNSS-PW Guide)	TT GNSS-PW	Dec 2015
25	Develop a GRUAN ozonesonde data product in consultation with NDACC and GAW. Completed technical documents	Greg Bodeker, Lead Centre	Dec 2015
26	Revise the RS-92 data stream based upon feedback received - revised version 3 release including qc flags vectors and data in different vectors (good, questionable, missing), including implementation of performance feedback. Validate new radiation correction using ancillary measures to build confidence (paper). Document v3 appropriately.	Lead Centre, TT radiosondes, TT ancillary measurements	March 2016
27	Technical documentation completed for frostpoint hygrometer measurements. In first instance send existing documentation to Greg Bodeker.	TT radiosondes	March 2016
28	Determine how best to work with NDACC and GAW to bring in measurements of aerosol properties into GRUAN. Produce short document outlining a proposed strategy.	WG Chairs, WG members, TT ancillary measures, Potenza, EARLINET	March 2016
29	Define the GNSSPW data collection client requirement, initiate data flow	TT GNSS-PW, Lead Centre	March 2016
30	Presentation(s) at ICM-8 summarizing strategy for dealing with transition from RS92 and initial analyses and implications	Lead Centre, TT Radiosondes, TT sites	April 2016
31	Redraft IP to be more a strategic plan document, perhaps with a somewhat longer timeframe but only milestones, not deliverables, to avoid dating issues. Draft document ready by ICM-8 for review and discussion.	WG Chairs, Lead Centre, TT Chairs	April 2016
32	Define the ozonesonde data collection client requirement, identify the central data processing facility, and initiate data flow	Greg Bodeker, Lead Cenre	April 2016
33	Investigate how GRUAN uncertainties could be transmitted over BUFR and how BUFR tables would require modification to enable this. Report at ICM-8.	GCOS Network manager, CBS, WG Chairs	April 2016
34	Demonstration study of SASBE to include impacts of arbitrary mix of observations and spatial/temporal mismatch in context of climate monitoring and SAT cal/val; focus on temperature, H20 vapor profile and uncertainty propagation (using SIGMA approach to define parameter- and site-specific mismatches).	TT ancillary measurements	April 2016
35	Periodic science review of network expansion priorities and progress. Report to ICM-8	Greg Bodeker	April 2016
36	GRUAN official launch event / celebration including some	Working Group, Lead	April 2016

	short relevant presentations and possibly posters. To be held at ICM-8 which will take us back to our roots where it all started.	Centre, TT Sites	
37	Manuscript(s) detailing operational considerations for controlled descents for frostpoint hygrometers submitted to a journal or detailed in a GRUAN Report	TT radiosondes	May 2016

Appendix D: ICM-7 agenda

Meeting to be held in Matera, Italy 23rd-27th February with support provided by CNR and US GCOS office.

Organizing Committee: Peter Thorne, Greg Bodeker (WG co-chairs), Ruud Dirksen (Lead Centre), Howard Diamond (US GCOS Office), Fabio Madonna, Gelsomina Pappalardo, Nico Cimini (local hosts), Belay Demoz, Dale Hurst (TT site representatives chairs)

Please ensure ample time for discussion. If a slot in Sessions 2 onwards does not have a dedicated follow-on discussion this means you should aim to present for at most 2/3 of the time allotted.

Items with the timeslot highlighted we expect a document in advance to be made available by the responsible parties. All documents should be with the Lead Centre no later than Feb 10th.

Monday

Day Chair: Fabio Madonna

Rapporteur: Tom Gardiner

8.30 - 8.50 Registration

Session 1 – Opening session and keynotes

8.50 – 9.00 Welcomes – local hosts, WG co-chairs

9.00 -9.20 GRUAN basics – Ruud Dirksen

9.20 – 9.50 GRUAN and EU infrastructure projects – Andreas Voltz-Thomas

9.50 – 10.10 GRUAN, CNR and Italian Met Service activities – Massimo Ferri

10.10 – 10.30 Coffee break

Session 2 – Review of progress in the past year

10.30 – 11.00 Lead Centre progress report – Ruud Dirksen and Michael Sommer

11.00 – 11.30 Assessment of progress against ICM-6 report action plan, discussion of Implementation Plan items – Peter Thorne and Greg Bodeker

Please note that TT reports should cover solely those aspects of TT work which will not be covered in subsequent sessions. Please avoid repetition. Please highlight in particular challenges, impediments and areas where help is required and/or that would benefit from WG discussion.

11.30 – 11.45 Task team progress report from TT radiosondes (to include managed descent and autolauncher task updates)

11.45 – 12.00 Task team progress report from TT GNSS-PW

12.00 – 13.00 Lunch

Rapporteur: Greg Bodeker

13.00 - 13.15	Task team progress report from TT scheduling
13.15 – 13.30	Task Team progress report from TT ancillary measurements
13.30 -13.45	Report from the GRUAN science coordinators
13.45 – 14.00	General discussion of progress

Session 3 – Radiosonde data streams

14.00 – 14.20	Development and certification of GRUAN data products – Michael Sommer / Holger Vömel
14.20 -14.40	The necessary steps required for developing Technical Documentation for radiosondes. The proposed format for radiosonde Technical Documents – Michael Sommer / Greg Bodeker
14.40 – 15.00	*Coffee break*
15.00 – 15.10	Collection of GRUAN oral histories – Dian Seidel
15.10 – 15.40	Version 3 of the GRUAN RS92 radiosonde data product – what is new – Ruud Dirksen
15.40 -16.00	Group discussion of the v3 RS92 product
16.00 – 16.30	The Meteolabor sonde data product – progress, plans and intercomparisons – Rolf Philipona
16.30 – 16.50	Group discussion of the Meteolabor sonde data product
16.50 – 17.15	The Modem sonde data product – progress and plans – Martial Haeffelin
17:15 – 17.35	Group discussion of the Modem sonde data product.
17.35 – 18.00	Managing the transition from RS92 to RS41 discussion – lead discussant: Ruud Dirksen

Optional evening round-table process discussions

20.00 – 21.00	The GRUAN site map – Greg Bodeker / Ruud Dirksen

Tuesday

Day chair: Peter Thorne

Rapporteur: June Wang

9.00 – 9.30 The Mesei sonde data product – progress (incl. comparison (RS-11G, RS92-SGP and other Reference sensor)) and plans – Nobuhiko Kizu

9.30 – 9.50 Group discussion of the Mesei sonde data product

9.50 – 10.15 The CFH data product progress – Holger Vömel

10.15 – 10.35 Group discussion of the CFH data product

10.35 – 11.00 Coffee break

Session 4. Homogeneity and metadata

11.00 – 11.20 What about cross-network homogeneity? - Michael Sommer/Ruud Dirksen

11.20 – 11.40 Update on GRUAN's interactions with the WIGOS metadata task team. – Arnoud Apituley

Session 5. Other GRUAN products

11.40 – 12.10 GNSS-PW progress – Markus Bradke

12.10 - 13.05 Lunch

Rapporteur: Dale Hurst

13.05 – 13.30 Lidar progress – Thierry Leblanc

13.30-13.45 Raman lidar observations in Payerne – Gianni Martucci

13.45 – 14.05 Progress towards GRUAN Microwave Radiometer product– Nico Cimini

14.05 – 14.20 MUSICA: FTIR H2O data – Matthias Schneider

Session 6. GRUAN and satellites

14.20 – 14.40 Follow-on actions for GRUAN from the 3G workshop – Greg Bodeker /Stephan Bojinski

14.40 – 15.10 Accurate Occultation Prediction with 4 Weeks Lead Time / Statistical Analysis of COSMIC Radio Occultation Data against GRUAN Sondes – Axel von Engeln

15.10 – 15.25 Coffee break

15.25 – 15.50 Consistency between GRUAN and IASI and the GRUAN/Satellite collocation uncertainty determination project – Xavier Calbet

15.50 – 16.05 GRUAN and GSICS – Viju John

16.05 – 16.20 The H2020 GAIA-CLIM project – Peter Thorne

16.20 – 16.45 Progress with NPROVS+ - Tony Reale

16.45 – 17.00 GPS-RO water vapour and GRUAN – Rob Kursinski

17.00 – 17.15 Active Temperature Ozone and Moisture Microwave Spectrometer ATOMMS – Rob Kursinski

Session 7. Extending GRUAN's reach

17.15 – 17.45 GRUAN and GUAN –Tim Oakley

17.45 – 18.15 Collaborations in GNSS sphere with other projects (GNSS4SWC, EGVAP) – Rosa Pacione / Jonathan Jones

Optional evening round-table science discussions

20.00 – 21.00 How to evaluate uncertainties in temperature measurements – Andrea Merlone

21.00 – 22.00 How to calculate a monthly mean and its uncertainty – Greg Bodeker

Wednesday – Sites day

Day Chair: Dale Hurst and Belay Demoz

Rapporteur: Peter Thorne

Session 8. The sites day

9.00 – 9.45 LC summary of site status and reports as in ICM-6 – Ruud Dirksen

GRUAN data flow from LC upload to GTS - LC/sites

9.45 – 10.00 Open discussion

10:00 – 10.20 FLEXPART Lagrangian model for Reunion and other activities at La Reunion - Stephanie Evan

10:20 – 10:35 *Coffee Break*

10.35 - 10.55 Measurement at Sodankyla – Rigel Kivi

10.55 – 11.25 Attempts to extend the Ny-Alesund dataset backwards - Marion Maturilli.

Meteomet collaboration with Ny Alesund – Andrea Merlone

11.25 – 11.45 Update on Lauder activities– Richard Querel

11.45 – 12.05 Metrology/meteorology at Potenza: perspectives - Fabio Madonna

12.05 – 12.15 Open discussion

12.15 – 13.15 *Lunch*

Rapporteur: Richard Querel

13.15 – 13.35 NWS-Sterling NASA/GSFC and Beltsville collaboration - Belay Demoz

13.35 – 14.05 ARM Climate Research Facility

1) Sonde activities: restructure and impact to GRUAN

2) Overview of ARM Lidar (Raman and Doppler) measurements - Lead: Doug Sisterson

14.05– 14.25 GNSS Analysis for Climate Monitoring and Meteorological Applications at ASI/CGS, Matera - Rosa Pacione

14.25 – 14.40 Open discussion

14.40 – 14.55 *Coffee break*

14.55 – 15.15 Ground-based observations performed by the Italian Met Service, Italian Met service – Stefania Vergari

15.15 – 15.35 Changes to the GUM and what it might mean for GRUAN – Andrea Merlone

15.35 – 16.30 Open mic: Discussion of Issues of the day and impromptu presentations from sites

16.30 – 18.00 Discussion of potential new sites in GRUAN including brief reports by nominated shepherds on progress – facilitated by Greg Bodeker

Site shepherds will be requested to provide a brief update to the wiki or via email (preference is wiki) to Greg Bodeker in advance.

Thursday – Site visit day

9.00 bus departs from Matera

10.15 welcome

10.30-10.50 CIAO: the CNR-IMAA Atmospheric Observatory and its role in the European and global scenarios - Gelsomina Pappalardo

10.50-11.10 The single calculus chain of EARLINET for the automatic processing of aerosol lidar data: an overview - Giuseppe D'Amico

11.10-11.30 CIAO activities for satellite validation and model evaluation using ground based measurements - Lucia Mona

11.30-11.50 Retrieval of water vapor and clouds properties from satellite platforms - Filomena Romano/Nico Cimini

11.50-12.10 Synoptic soundings in Italy and migration to RS41 radiosonde -Maria Rita Leccese

12.10-12.50 Discussion on the ACTRIS/GRUAN synergy

12.50 – 13.30 *Lunch and posters viewing*

13.30 – 15.00 Potenza site tour in two groups

15.00 – 15.15 Coffee break

15.15 – 18.30 short trip around Basilicata region

18.30 Arrival in Matera

20.00 Workshop dinner

Friday

Day Chair: Nico Cimini

Rapporteur: Arnoud Apituley

Session 9. GRUAN management and communication

8.00 – 8.20	The GRUAN launch event – Greg Bodeker
8.20 – 8.40	Discussion on the GRUAN/GAW collaboration - Geir Braathen
8.40 – 9.05	Discussion around whether WG members' terms should be fixed terms or not – Peter Thorne
9.05 – 9.35	Discussion of GCOS ECV tables and GRUAN – Tim Oakley
9.35 – 10.05	Content management of the GRUAN website and its communication tools – Michael Sommer / Greg Bodeker
10.05 – 10.20	*Coffee break*
10.20 – 11.50	The GRUAN work plan for 2015/16 – Peter Thorne
11.50 – 12.20	Close

Appendix E: Lead Centre Report

GRUAN Lead Centre progress report 01/2015

covering the period 02/2014 to 01/2015

Author

Ruud Dirksen

GRUAN Lead Centre

Lindenberg Meteorological Observatory – Richard Aßmann Observatory

Deutscher Wetterdienst

Summary

Boulder and Lauder are official GRUAN certified sites. Cabauw, Payerne, Potenza, and Sodankyla are currently going through the process of certification.

The head of the Lead Centre stepped down, recruitment of new LC head in progress.

The GRUAN Lead Centre has participated in several conferences and workshops.

The GRUAN Lead Centre participated in campaign at La Reunion.

Preparation of ICM-7.

Development of GRUAN data processing for RS92 v3.

Health of network

ARM has terminated their activities at Manus and Darwin. Continuation of Darwin as a GRUAN site under responsibility of BOM is being negotiated. The French sites Paris (SIRTA) and La Reunion will join GRUAN.

Lead Centre operations

- The Lead Centre participated in the preparation of ICM-7.
- Data flows from Beltsville and Lauder are up and running. Data flow from Payerne, Vaisala RS92 and Meteolabor SRS34, is up and running as well.
- Visits by Meisei and Modem, their radiosondes were tested in the Lindenberg facilities (radiation, RH calibration & time lag).
- Testing and characterization of Vaisala RS41.
- Ongoing development of RsLaunchClient.

Progress against stated objectives

Open items	**Summary of progress**
3. Responses to requests from sites for letters from WG-GRUAN / GCOS to be actioned. Letters to be drafted and sent. Letters requested in site reports or at ICM-6	Only Potenza followed up. Letter was drafted and forwarded to GCOS secretariat.
5. Prepare plan for GRUAN launch activity at WMO congress and report plan to GRUAN community at ICM-7	In progress, Greg Bodeker is leading this. Talk scheduled at ICM-7.
6. Define necessary steps to undertake transition from RS92 to RS41.	In progress, talk scheduled at ICM-7.
8. To close the feedback loop for instrument and processing performance, TT sites to summarize how they wish to receive near real-time feedback.	Done, TT has sent their recommendations to LC.
10. TD omnibus of all things RS92. Lead Centre to send everything to Bodeker Scientific for collation and editing. Gaps to be identified and Lead Centre will try to address the gaps. Greg Bodeker and Peter Thorne to determine how to accommodate updates.	Superseded. Discussions with Lead Centre led to proposal to instead have a radiosonde omnibus with per instrument technical annexes. To be discussed at ICM-7. How to accommodate updates has been addressed and published as GRUAN-TN-2.
11. Technical documentation completed for frostpoint hygrometer measurements	In progress, talk at ICM-7 will update on progress and work still required.
12. A short GRUAN report detailing the process implemented to provide feedback of observation minus background fields to the GRUAN Lead Centre	Good progress, ECMWF has developed infrastructure to make feedback data available via a user-friendly web-interface. First tests with the feedback data will be in the first half of 2015. This activity will complement Gaia-Clim.

13. Sites reporting either TEMP or not reporting on the GTS / WIS to work with Lead Centre, WIGOS and HMEI to ensure GRUAN sonde launches are sent as 2 s resolution BUFR. Briefly report progress and issues to ICM-7. Data flowing through WIS as BUFR high vertical resolution for as many sites as possible.	Some progress. Details of how to start this process have been shared with LC.
22. Develop frostpoint hygrometer data products. Guidance needs to account for operation of CFH, NOAA FPH. Paper submitted to a peer reviewed journal	Partially met. Independent ground check developed for CFH but final analysis and write up still pending.
21. In collaboration with partner networks, assess the relevance and tractability of the full suite of remaining GRUAN target variables defined in GCOS112 in the context of measurement capabilities and measurement programmes underway in partner networks. GRUAN report identifying potential target data streams and partners	Not done. In view of limited resources, other actions were given higher priority.
23. Develop a GRUAN ozonesonde data product in consultation with NDACC and GAW. Completed technical documents	No progress. Need to find a new workable solution. Greg has been working with Anne Thompson to find someone available to assist. Funding is available.
24. Lead Centre to report on data usage / impact metrics (following recommendations from #2) to extent possible	In progress. LC has compiled a list of GRUAN-related publications/presentations.
25. Revise the RS92 data stream based upon feedback received - revised version 3 release including QC flags vectors and data in different vectors (good, questionable, missing), including implementation of performance feedback	In progress. The current state of development of v3 will be discussed at ICM-7.
28. Develop GRUAN data product and processing stream for Modem radiosondes. First draft of technical document describing processing streams for all Modem radiosondes	In progress, talk at ICM-7 will update on progress and work still required.
30. Develop an advanced 'template document' for non-RS92 radiosondes for later distribution to specific users	Superseded by the suggestion for radiosonde omnibus with per instrument technical annexes.
33. Reports from WG and GRUAN community members on efforts to further contributory site set. Single page write ups for each site by selected GRUAN leads at ICM-7 (list of sites and contact points in main report) and also reports on phone calls	Partially met pending receipt of written reports and their presentation.

Achievements

- *Boulder and Lauder have become GRUAN certified sites.*
- *Certification procedure of Cabauw, Potenza, Payerne, Sodankyla still ongoing.*
- *The description of the Version 2 processing algorithms for the RS92 GRUAN data product has been published in AMT (DOI: 10.5194/amt-7-4463-2014).*
- Ongoing development of RsLaunchClient (current version: 0.5)
- Agreement with GFZ for a cooperation to develop a GNSS data product. This project is funded by LC.

Training by Lead Centre

- Training of AWI staff going to Ny Alesund
- Training and assisting staff at La Reunion in preparation and launch of CFH.

Issues

- The head of the Lead Centre *stepped down*, recruitment procedure in progress.

Work plan for next six months

- Appoint new head of Lead Centre.
- Completion of Cabauw, Sodankyla, Payerne, and Potenza site certification application.
- Work on the GRUAN radiosonde omnibus.
- Redesign the GRUAN website and its communication tools to facilitate more flexibility regarding content management, e.g. shared editing permissions for certain parts of the website.
- Complete the development of a new GRUAN data processor, and version 3 of the RS92-GDP. This version will digest DC3DB and MWX file formats.
- Develop a GNSS data product. LC-funded cooperation with GFZ.

Appendix F: Task Team Radiosonde Progress Report

Task Team progress report for February 2015
(Submitted by Masatomo Fujiwara and Rolf Philipona)

SUMMARY
We have currently 4 main tasks and 4 additional tasks. We have been working on the 4 main tasks very actively; however, we need to change the due date because we need more time to complete them.

This table shows the current members of the team. Three new researchers jointed the team in 2014.

Name	Affiliation	Status
Masatomo Fujiwara	Hokkaido University, Japan	Co-chair
Rolf Philipona	MeteoSuisse, Switzerland	Co-chair
Ruud Dirksen	GRUAN Lead Centre, DWD, Germany	
Frank Schmidlin	USA	
Alexander Kats	Central Aerological Observatory/KOMET, Russia	
Hannu Jauhiainen	The Association of Hydro-Meteorological Equipment Industry; Vaisala, Finland	HMEI representative
Micheal Hicks	**NOAA/NWS/OOS, USA**	
Larry Miloshevich	MILO-Scientific, USA	
Rigel Kivi	Finnish Meteorological Institute, Finland	
Nobuhiko Kizu	Japan Meteorological Agency, Japan	
LI Wei	China Meteorological Administration, China	
Yang RongKang	**China Meteorological Administration, China**	
Martial Haeffelin	**Institut Pierre Simon Laplace, France**	
Holger Vömel	**NCAR/EOL, USA**	

PROGRESS ON THE 4 MAIN TASKS

Task: *Assess time lag in Vaisala RS92 humidity corrections, comparing the GRUAN processing to other published approaches.*
Main Contact: *Ruud Dirksen with assistance from Michael Sommer, Larry Miloshevich, Masatomo Fujiwara and Alexander Kats*
Due Date: *31-Dec-2015 (changed)*
Status: *Ongoing*
Milestone: *Manuscript describing the results of the humidity time lag assessment submitted to a journal.*
Progress: *Test calculations were made by Larry Miloshevich and by Ruud Dirksen. Restarted in late 2014, after the publication of Dirksen et al. (AMT, 2014) on description of the GRUAN Vaisala RS92 data product version 2.*
Issues: *None.*

Task: *Assess the effects of the use of auto-launchers compared to manual launches on measurement uncertainty estimates for radiosondes.*
Main Contact: *Rigel Kivi, Nobuhiko Kizu, and Fabio Madonna*
Due Date: *31-Dec-2015 (changed)*
Status: *Ongoing*
Milestone: *Publication in the peer reviewed literature.*
Progress: *Information has been summarized at Sodankyla (Kivi), Potenza (Madonna), and Tateno (Kizu). Still in the process to finalize the analyses.*
Issues: *None*

Task: *Assess controlled descent mechanisms for balloon payloads and issues around use of descent data*
Main Contact: *Rolf Philipona, Dale Hurst and Masatomo Fujiwara*
Due Date: *31-Dec-2015 (changed)*
Status: *Ongoing*
Milestone: *Manuscript(s) detailing operational considerations for controlled descents submitted to a journal or detailed in a GRUAN Report. If deemed applicable, a technical document that supports the adoption of controlled descent across GRUAN.*
Progress: *Regular descent sounding is made at Boulder and Lauder. Some experiments were made at Lindenberg, Payerne, NCAR (and under a tropical project named SOWER).*
Issues: *Still in the experimental phase.*

Task: *Assess multi-payload launch configurations for GRUAN usage.*
Main Contact: *Hannu Jauhiainen and Masatomo Fujiwara*
Due Date: *31-Dec-2015 (changed)*
Status: *Ongoing*
Milestone: *Document detailing the issues surrounding multi-payload soundings to be drafted and submitted either to peer reviewed literature (first choice) or to WG-GRUAN for review as a TD*
Progress: *A draft manuscript is being prepared; various options and their pros and cons are described there.*
Issues: *Can we make a single recommendation? TD or AMT?*

NOTES ON THE 4 OTHER TASKS
(The primary contact for these tasks is the Lead Centre. The Task Team Radiosonde is to help and support the Lead Centre's work.)

Task: *Define the non-RS92 data collection client requirement, identify the central data processing facility, and initiate data flow.*
Milestones: *Assessments of non-RS92 data collection client requirements. Data flow through NCDC portal*

Task: *Develop a UT/LS water vapour data product supported by appropriate technical documentation. The technical documentation must account for operation of CFH, NOAA FPH, Snow White and possibly FLASH-B.*
Milestone: *Technical documentation completed for frostpoint hygrometer measurements. Peer reviewed publication on frost point hygrometer GRUAN data product submitted.*

Task: *Finalize the definition of GRUAN data products for RS92 radiosondes: Technical document describing pre-launch procedure (TD5)*
Milestone: *Review of the pre-launch ground-check/ground-calibration procedures*

Task: *Define the ozonesonde data collection client requirement, identify the central data processing facility, and initiate data flow.*
Milestone: *Data flow through NCDC portal. Assessment of data usage, issues and potential improvements for this data stream.*

Appendix G: Task Team GNSS-PW Progress Report

Task Team progress report for February 2015

(Submitted by June Wang and Kalev Rannat)

SUMMARY

The TT has worked on topics listed on the GRUAN Master Action Item list:

a) Manuscript describing the derivation of uncertainty estimates for GNSS-PW measurements submitted to a peer reviewed journal. In progress. A draft was done in 2014. Funding was secured to complete this in 2015. The deadline for submission is September 1, 2015.
b) Develop a GRUAN GNSS-PW product. Technical documentation completed for GNSS-PW measurements (GNSS-PW Guide).

Parallel work is going on with:

- Completing a set of GRUAN technical documents describing all aspects of GNSS-PW data flow: Sent all documents to Emma Scarlet in September, 2014, and it will be done soon.
- Assessment of data usage, issues and potential improvements for this data stream (GNSS TT 1. Sept. 2016).
- Close collaborations with GNSS4SWEC Climate working group.

Besides working on issues listed above, the GNSS-PW TT has also been involved in the following activities:

1. GNSS data flow and processing: The work is in progress, new connections to Lauder and Sodankyla. A lot of technical help was offered by GFZ (Markus). Additional/continuous work needed for supporting met-RINEX data flow and connecting more GNSS-data streams to LC and GFZ. After the data can be regularly obtained from the sites, the next step will be specifying the needs for related metadata and how to develop a software tool for GNSS-data (like Radiosonde client).
2. Kalev & Galina processed Lauder GNSS-data for ZTD and IPW, comparing with radiosonde.
3. New ToR for GNSS-PW TT was finalized and posted on GRUAN web site.

Appendix H: Task Team Scheduling Progress Report

Task Team progress report for February 2015 – Scheduling Task Team

(Submitted by Tom Gardiner and Dave Whiteman)

SUMMARY

The primary objective for the Task Team is to develop defensible, quantifiable, scientifically-sound guidance for GRUAN sites on measurement schedules and associated site requirements, in order to meet the GRUAN objectives.

In terms of scientific outputs from the Task Team, while the activities of the team remain a voluntary one without specific funding the main information sources are from the peer-reviewed literature, GRUAN documentation, and currently unpublished studies of which the group is aware. Some limited new analyses are being undertaken by Team members using existing data sets to start to address areas where critical gaps exist that prohibit scientifically defensible choices.

In addition to the progress on the tasks described below, other activities this year have included :

- Publication on the uncertainty due to temporal mismatch. When intercomparing different temperature profiles it is important to include the effect of temporal mismatch between the measurements. This paper addresses the coincidence uncertainty associated with using radiosonde results for intercomparisons with other temperature measurements using long term data records from Lindenberg and ARM-SGP sites and the high-density 6-month data set from Manus during the Dynamo campaign. The extension of the application to the global scale using model data is planned.
    - *Butterfield, D. and Gardiner, T.: Determining the temporal variability in atmospheric temperature profiles measured using radiosondes and assessment of correction factors for different launch schedules, Atmos. Meas. Tech., 8, 463-470, doi:10.5194/amt-8-463-2015, 2015.*

PROGRESS ON CURRENT TASKS

Task: *Extension of trend sensitivity studies to include stratospheric water vapour and also extension of trend studies into the LS.*

Main Contact: *Dave Whiteman* **Due Date:** *31-Dec-13* **Status:** *On-going*

Milestone: *Paper on extension of trends sensitivity studies analysis to stratospheric water vapour and submission to a peer reviewed journal.*

Progress: *A draft paper on 'Lower Stratospheric Water Vapor Trend Detection – Needs and Current Assessment' was submitted to Journal of Geophysical Research - Atmospheres. This studies the needs for and current capabilities of water vapor trend detection in the lower stratosphere using data from balloon-borne frostpoint hygrometer (FPH) and Microwave Limb Sounder (MLS).*

Issues: *Some issues raised by reviewers need further investigation – work continuing on an ad-hoc basis. Disagreement between FPH and MLS in past 12-18 months has complicated analysis. Plan now is to disregard most recent data for the purposes of this paper.*

Task: *Review of temperature scheduling requirements (as already done for WV in the Guide) for scheduling decision support.(Update)*

Main Contact: *Tom Gardiner* **Due Date:** *30-Sep-13* **Status:** *Completed*

Milestone: *Report on temperature scheduling requirements.*

Progress: GRUAN report 3 *'Review of Operational Requirements for Temperature Sonde Measurements' published in May 2014. This review brings together the information in the peer-reviewed literature to provide guidance to the GRUAN community on the requirements for sonde temperature measurements, covering aspects such as measurement scheduling, measurement uncertainty, change management and network design.*

Issues: *None*

Appendix I: Task Team Ancillary Measurements Progress Report

Task Team progress report as of Feb. 2015

(submitted by Thierry Leblanc and Tony Reale)

SUMMARY

The task team on ancillary measurements oversee the production and integration of ancillary measurements, namely MWR, FTIR and ground-based lidar in compliance with GRUAN best measurement practices. Satellite observations also provide a source of ancillary measurement and their integration for use in overall validation, weather and climate applications is facilitated by the team. The composition of the task team remained unchanged over the past 12 months.

During 2014, procedures were implemented to begin access and collocation of GRAS GPSRO profiles and observations into NPROVS and NPROVS+ collocation datasets. Work continued to better integrate "uncertainty" analysis in routine satellite products validation including the added processing of "dedicated" RS92 RAOB, funded by NOAA, using GRUAN reference processing software. Progress continued toward procedures to compute site atmospheric state best estimates (SASBE) and associated SIGMA profiles for expanded sets of ancillary measurements from a given site using specific site recipe. Finally, over 6000 collocations of GRUAN and selected dedicated (w/S-NPP) RAOBs were added to NPROVS+ since ICM-6.

As part of the 2014 efforts towards future GRUAN Lidar data stream, a prototype version of the GRUAN Lidar Analysis Software Suite (GLASS) was developed. The software is capable of analysing raw signals of 9 different instruments, including 3 potential GRUAN lidar instruments (Payerne, Ny-Ålesund and Potenza), and 4 NDACC lidars. The current products of the GLASS are: water vapour, tropospheric ozone, stratospheric ozone, and temperature. No aerosol-related product is expected for the next 1 year. The GLASS uses the standardized definitions of vertical resolution and uncertainty recommended by the ISSI Team on NDACC Lidar Algorithms, as well as the recommended standardized approach for the propagation of these uncertainties through the data processing chain. The recommended approaches and definitions are compiled in the now-finalized ISSI Team Report, distributed this month to the NDACC Lidar Working Group for review and comments, and will be used to update and finalize the GRUAN Best Measurement Practices and Lidar Guidelines (expected June 2015).

For FTIR, Best Measurement Practices and Guidelines document is being written. A comprehensive review of the FTIR uncertainty budget for the MUSICA H2O and HDO/H2O products is given in Schneider et al. , 2012 (AMT, 5, 3007, 2012). A new paper reporting on a MUSICA validation campaign is Schneider et al., 2015 (AMT, 8, 483, 2015).

On the Microwave side, similar Best Measurement Practices and Guidelines documents are being written. The current draft version (V0.8) has Sections 1,2,3 completed. Sections 4-9 are currently being drafted. A complete draft version (V1.0) is expected by June 2015. A suitable data format compliant to NetCDF Climate and Forecast convention has been organized in the framework of the German HD(CP)2 Project . MWR data in Cabauw and Lindenberg (as well as other sites) are already processed based on this "Observation Data Product Standard". A review of the MWR calibration and uncertainty budget is currently in progress within the EU COST Action TOPROF. In the TOPROF framework the Joint Calibration (J-CAL) experiment, a field test involving 5 colocated microwave radiometers, was performed in August 2014 at the premise of the LC in Lindenberg. A first version of the J-CAL scientific report is available. The final J-CAL scientific report is expected within the first half of 2015. Results from J-CAL as well as from the uncertainty budget analysis will be reported into the GRUAN MWR Guidelines.

See progress on individual action items starting next page.

PROGRESS ON CURRENT TASKS/ACTION ITEMS:

(action item numbers listed according to Master Action Item List available at: *https://docs.google.com/spreadsheet/ccc?key=0Aq9hAcrcg9GtdEJDZkRWdGtUQXZ1YjZQNjJTLUUyYUE&usp=sharing*)

Action Item 2: Retain collocated satellite radiances within (or linked) from the NPROVS+ archive for inter-radiance comparisons.

Main Contact: **T.** Reale **Due Date:** 3/2015 **Status:** Ongoing

Milestone: **v1 Algorithm Support Dataset Created**

Progress: **Testing Underway**

Issues: NETCDF, not publically available (yet), only for S-NPP

Action Item 3: Demonstration study of SASBE to include impacts of arbitrary mix of observations and spatial/temporal mismatch in context of climate monitoring and SAT cal/val; focus on temperature, H20 vapor profile and uncertainty propagation (SIGMA).

Main Contact: T. Reale, J. Dykema, D Tobin **Due Date:** 3/2015 **Status:** Ongoing

Milestone:

Progress: Identified for GRUAN Science Investigation (T. Gardiner)

Issues:

Action Item 4: Utility of NPROVS+ dataset management and graphical tool to support GRUAN (RAOB, AM, SASBE …) "profile" developers

Main Contact: T. Reale, T. LeBlanc, **Due Date:** 12/2016 **Status: re-defined**

Milestone:

Progress: Topic for discussion within TTAM

Issues: New topic, original Action 4 (SASBE) merged into Item 3

Action Item 5: Report on use of satellite collocation data (NPROVS+) as QC/QA tool for GRUAN Data Products

Main Contact: T. Reale & M. Sommer **Due Date:** 3/2015 **Status:** Ongoing

Milestone: Preliminary tool completed

Progress: 2014 report to be presented ICM

Issues:

Action items 18: Report on FTIR best measurement practices and suitability of equipment (FTIR Guidelines)

Main Contact: J. Hannigan & M. Schneider **Due Date:** 12/2013 **Status:** Ongoing

Milestone:

Progress: Unfortunately there have been no actions in this respect during last year

Issues:

Action items 19: FTIR technical documentation (FTIR Guide) submitted for review by WG-GRUAN

Main Contact: TT-AM **Due Date:** 3/2015 **Status:** Ongoing

Milestone:

Progress: Unfortunately there have been no actions in this respect during last year

Issues:

Action items 20: Papers describing GRUAN FTIR products (MUSICA products) submitted for peer review

Main Contact: J. Hannigan & M. Schneider **Due Date:** 3/2015 **Status:** Publications in AMT

Milestone:

Progress: Schneider et al. (2012): AMT, 5, 3007, 2012

Schneider et al. (2015): AMT, 8, 483, 2015

Issues:

Action items 21: Report on consistency between FTIR and IASI retrievals of products for H2O and HDO/H2O

Main Contact: M. Schneider **Due Date:** 12/2016 **Status:** Publications in AMT

Milestone:

Progress: Wiegele et al. (2014): AMT, 7, 2719, 2014

Schneider et al. (2015): AMT, 8, 483, 2015

Issues:

Action items 22: Data flow through NCDC portal

Main Contact: LC and TT-AM **Due Date:** 9/2015 **Status:** Not started

Milestone:

Progress: No progress for NCDC portal, but submission to NDACC database is in preparation. It is still not finished due to some discussions on the modification of the metadata standard needed for the MUSICA data.

Issues:

Action items 23: Assessment of data usage, issues and potential improvements for this data stream

Main Contact: TT-AM **Due Date:** 12/2016 **Status:** Not started

Milestone:

Progress:

Issues:

Action items 39: Inventory of AERI instruments to be compiled for TTAM consideration and report to GRUAN community on viability to bring AERI into GRUAN.

Main Contact: M. Schneider & J. Hannigan **Due Date:** 2/2013 **Status:** Ongoing

Milestone:

Progress:

Issues:

Action items 24: Report on microwave radiometer best measurement practices and suitability of equipment (Microwave Radiometer Guidelines)

Main Contact: N. Cimini **Due Date:** 3/2015 **Status:** Ongoing

Milestone: Version 0.8 delivered before ICM-7.

Progress: Sections 1, 2, 3 are nearly completed. Sections 4-9 are being drafted.

Issues: Behind schedule

Action items 25: Inventory of potential microwave radiometer instruments for use in GRUAN (first version with semi-annual updates)

Main Contact: N. Cimini **Due Date:** Recurring **Status:** Ongoing

Milestone: Version 0.1 will be delivered after ICM-7.

Progress: Most of the actual GRUAN sites have been inventoried.

Issues: None

Action items 26: Report on validation strategies and results for microwave radiometers

Main Contact: N. Cimini **Due Date:** 12/2015 **Status:** Ongoing

Milestone:

Progress: Validation statistics are available for some GRUAN sites and will be reported on GRUAN microwave radiometer guidelines. Observation minus model background (O-B) statistics at selected GRUAN sites are planned within the EU COST Action TOPROF (a focused sub-WG meeting is scheduled for March 2015).

Issues: None

Action items 27: Microwave radiometer technical documentation (Microwave Guide) submitted for review by WG-GRUAN

Main Contact: TT-AM **Due Date:** 6/2015 **Status:** Just started

Milestone: Version 0.8 delivered before ICM-7. Version 0.8 is uncompleted.

Progress:

Issues:

Action items 28: Paper describing the GRUAN Microwave radiometer product submitted for peer review

Main Contact: N. Cimini & N. Kampfer **Due Date:** 7/2015 **Status:** Not started

Milestone:

Progress:

Issues:

Action items 29: Data flow through NCDC portal

Main Contact: LC & TT-AM **Due Date:** 9/2015 **Status:** Not started

Milestone:

Progress:

Issues:

Action items 30: Assessment of data usage, issues and potential improvements for this data stream

Main Contact: TT-AM **Due Date:** 12/2016 **Status:** Not started

Milestone:

Progress:

Issues:

Action items 31: Technical documentation for GRUAN Lidar stream (Lidar Guide) submitted for review by WG-GRUAN

Main Contact: T. Leblanc and TT-AM **Due Date:** 12/2014 **Status:** Stalled

Milestone: When published as WMO/GRUAN TD

Progress: Version 1 written, revised version expected fall 2015

Issues: No progress in 2013 2014, but alignment with new GLASS now in progress

Action items 32: Paper describing GRUAN lidar products submitted for peer review

Main Contact: T. Leblanc and TT-AM **Due Date:** 6/2015 **Status:** Not started

Milestone: When published

Progress: Awaiting completion of GLASS and GRUAN TD

Issues:

Action items 33: Report on lidar products and uncertainty budgets developed by the ISSI Team on NDACC lidar algorithms.

Main Contact: T. Leblanc **Due Date:** 12/2014 **Status:** Ongoing

Milestone: 2015: Expected publication

Progress: Almost complete**;** Report finalized, to be reviewed by NDACC LWG

Issues: Slow progress due to lack of time availability

Action items 34: Report on lidar best measurement practices and suitability of equipment (Lidar Guidelines)

Main Contact: T. Leblanc **Due Date:** 12/2014 **Status:** ??

Milestone: ??

Progress: ??

Issues: Not sure what this item is for (isn't it covered in items 31-33?)

Action items 35: Report at ICM5 on status of EARLINET centralized data processing algorithm and possible synergies between EARLINET and GRUAN.

Main Contact: A. Apituley **Due Date:** 4/2015 **Status:** Ongoing?

Milestone: ??

Progress: **??**

Issues: Arnoud, could you address this please? Thanks

Action items 36: Report on progress towards developing a LIDAR data stream including run clients and uncertainty estimates.

Main Contact: T. Leblanc **Due Date**: 2/2015 **Status:** Ongoing

Milestone: When data stream is fully linked together (2015)

Progress: GLASS, 80% done, LidarRunClient 50%, Data Management: 0%

Issues: Slow progress due to lack of time availability

Action items 37: Data flow through NCDC portal

Main Contact: LC and TT-AM **Due Date:** 9/2015 **Status:** Not started

Milestone: When data stream is fully linked together (2015)

Progress:

Issues:

Action items 38: Assessment of data usage, issues and potential improvements for this data stream

Main Contact: T. Leblanc and TT-AM **Due Date:** 12/2016 **Status:** Not started

Milestone:

Progress:

Issues:

Appendix J: Task Team Site Representatives Progress Report

Task Team progress report for February 2015

(submitted by Dale Hurst and Belay Demoz)

SUMMARY

The **task team of site representatives** continues to serve as the conduit through which information and requests from the Lead Center and Working Group are disseminated to the GRUAN measurements sites. During the last 6 months two proposals created by the task team co-chairs were sent to the site representatives for their suggestions and comments. The feedback was incorporated into documents that were forwarded to Lead Center.

The composition of the task team has changed as follows:

Ruud Dirksen is temporarily serving as the site representative for the Lindenberg site.

Other reps from new sites:

- Beltsville, MD. USA has added an alternate representative Dr. Ricardo Sakai.

PROGRESS ON CURRENT TASKS

Task: To close the feedback loop for instrument and processing performance, TT sites to summarize how they wish to receive near real-time feedback.

Main Contact: Dale Hurst and Belay Demoz **Due Date: June 2014**

Status: Completed 30-October-2014

Milestone: Suggested content and methods of feedback on RS92 soundings from TT6 co-chairs and site reps compiled and forwarded to the Lead Center.

Progress: Completed

Issues:

Task: Each site to produce a proposal of how they will document by photos seasonal and long term site changes (regular e.g. quarterly from stated locations / daily webcam shotsetc. as appropriate to their specific case, and 'on change'). Proposals collated and documented for WG-GRUAN review and feedback.

Main Contact: Belay Demoz and Dale Hurst **Due Date: Nov 2014**

Status: Completed 12-January-2015

Milestone: A generic plan for all sites was composed, sent to site reps for comments, revised by the TT6 co-chairs, and forwarded to the Lead Center.

Progress: Completed

Issues: *Site-specific plans need to be developed by site representatives*

Appendix K: Site Reports

GRUAN Station Report for Beltsville

Reporting for the period Mar 2014 to Jan 2015
Date: 2015-01-31

Primary author: Ricardo Kendi Sakai (email: ricardo.k.sakai@howard.edu)
Secondary author: Belay B Demoz (email: bdemoz@umbc.edu)

Overview

The Howard University Beltsville Research site (HUBR), as a part of the Beltsville Center for Climate System Observation, is one of the GRUAN sites. The Beltsville site performs routine measurements of upper air sondes for GRUAN and elects to launch the sondes during the NPP overpass times at nighttime. It satisfies both GRUAN requirement and it serves as sonde-based satellite validation activities. The site has been launching state-of-the-art Vaisala GPS rawinsondes (RS92-SGP) coincident with the Suomi National Polar-orbiting Partnership satellite (NPP) satellite overpass to minimize the sonde-satellite mismatch errors and radiosonde quality issues. Data are being stored in the local computer, and send to GRUAN database through RsLaunchClient.

Since 2004, HUBR has operated an upper air ozone sonde station. The main objectives are understand summer pollution episodes to support Maryland Department of Environment (MDE) pollution monitoring, establishment of climatological statistics and application of these statistics and case studies for model formulation and optimization of satellite algorithms by HUBR collaborators, and quantification of the annual and inter annual variability of tropospheric O_3 (regional transport, stratospheric/tropospheric exchange, lightening, anthropogenic) and its impact on surface level air quality and air quality model predictability.

Recently, HUBR started its Cryogenic Frost Point Hygrometer (CFH) launches, in collaboration with the NDACC-related work of the NASA Goddard (NASA/GSFC) partners, to study upper tropospheric moisture and temperature variability. The reference flights will be done with the RS92-SGP launches. Since it is launched close to NPP overpass, it provides useful calibration/validation information regarding upper atmospheric water vapor measurements. Other current and future NASA satellite overpasses might be included in the future.

Change and change management

Even though Dr. Belay Demoz has been the director of Joint Center for Earth System Technology at University of Maryland, Baltimore County (JCET, UMBC) since April 2014, he still coordinates GRUAN efforts at HUBR. Thus, there is no change in personnel. Dr. Sakai has been added as a primary Howard University Personnel.

On October 18, 2014, HUBR started to launch the CFH probes.

On October 30, 2014, new Vaisala ground station, MW41, was installed and operational in substitution to Vaisala MW31 system. A lengthy change-management was not possible because of a fire-experienced at the site prior to ICM6. The site is, however, ready, to implement any and all backward compatibility in discussions with LC.

On December 15, 2014, HUBR impose the ground check CG25 parameters (pressure ±1.5 hPa, temperature ±1 K, RH ±2 %) provided from Dr. Michael Sommer to the MW41 software.

On January 4, 2015, the forecast balloon trajectory has been incorporated for launch decision to avoid premature radiosonde signal loss. If the balloon at 10 km high travels horizontally farther than 1.5^o from origin, the launch would be cancelled.

Resourcing

The site is the only a university site in GRUAN– very different from an operational, national site. As such, all the funding for GRUAN activities are derived from proposal and collaborations. This forces us to be open to collaborations with partners. The recent additions and growth in collaboration will be reflected in the certification document.

Site assessment and certification

In the process of certification – and goal is to submit prior to the ICM7 meeting.

GRUAN related research

Ozone summer pollution episodes and yearly climatology is a long-term goal we undertake in collaboration with the state of Maryland and NASA/GSFC – SHADOZ network.

Monthly CFH studies have commenced.

Highly collaborative work is progressing in satellite-sonde validation work with NESDIS/STAR and Tony Reale's group.

Wind lidar activities and lidar water vapour mixing ratio work is progressing in collaboration with NASA/GSFC. First-principle based calibration of Raman lidars has been published.

WG-GRUAN interface

Belay Demoz chairs the GRUAN sites task group and is a member of the GRUAN working group. David Whiteman, Belay Demoz, Mike Hicks are members of the GRUAN working.

Belay Demoz chairs the GRUAN sites task group

David Whiteman is a member of the scheduling task group and is contributing to the lidar studies group.

Mike Hicks and Jim Fitzgibbon are members in the radiosonde task group.

Working group can help by providing direction to the overall planning and collaboration of the site with other organization in its vicinity: this include a planned proposal by NOAA/NWS to contribute in much more to GRUAN activity.

Items for ICM-7 plenary discussions

Proposed collaboration with NWS-Sterling and other links that are being seeded by Howard University on GRUAN collaboration.

Future plans

Use of the Standard Humidity Chamber, Dr. Schulz & Partner GmbH, model SPRH100 for radiosonde quality assurance. Use of new vaisala radiosonde RS41, and intercomparison of RS92-SGP and RS41.

GRUAN Station Report for Boulder

Reporting for the period Feb 2014 to Feb 2015

Date: 17-Feb-2015

Primary author: Dale Hurst email: Dale.Hurst@noaa.gov

Overview

Currently only the weekly RS92 sounding data from Boulder are being processed into a GRUAN data product. We also regularly submit sounding data from ozonesondes (ECC) and the NOAA frost point hygrometers (FPH) when these instruments are part of the RS92 payload. It is envisioned that both the ECC and FPH data from Boulder will become GRUAN data streams in the near future. Other data streams available include GNSS-IPW from the Marshall Field Site near Boulder (and potentially the NCAR Foothills Lab in Boulder), Dobson and FTIR measurements of column ozone, and FTIR measurements of column water vapor, CO2 and methane. For more details of potential data streams see the “New Data Streams Survey” for Boulder that was submitted to the Lead Center in December 2013.

Change and change management

The Boulder site now almost exclusively uses Intermet radiosondes to transmit ECC and FPH data to the ground. An occasional RS80 radiosonde is launched when we perform a water vapor sounding with an older model CFH. An RS92 radiosonde is now part of every payload launched at Boulder. Prior to launch the RS92 sonde continues to be ground-checked with the GC-25, but is now also checked in the 100% RH chamber since mid-September 2014.

Resourcing

The Global Monitoring Division within the Earth System Research Laboratory of NOAA continues to support its many long-term monitoring programs in the face of reduced or flat federal funding while equipment and personnel costs rise. We depend on federal funds from GMD to continue our weekly RS92 + ECC soundings and monthly RS92 + FPH + ECC soundings at Boulder and Hilo, Hawaii and to support the monthly RS92 + FPH + ECC soundings at Lauder, New Zealand. Financial assistance from GCOS continues to greatly improve our program’s ability to continue at Lauder. Our capability to continue GRUAN-related activities at Boulder depends largely on the future of GMD’s federal funding.

Site assessment and certification

The Boulder site was officially certified on September 9, 2014, by the GRUAN Lead Center and Working Group for its Vaisala RS92 radiosonde soundings.

GRUAN related research

The NOAA FPH was part of the AquaVIT-2 water vapor measurement intercomparison campaign conducted in April 2013 at the AIDA environmental chamber in Karlsruhe, Germany. There were ~20 different instruments measuring chamber-controlled water vapor mixing ratios from less than 1 ppm to several thousand ppm over a wide range of chamber pressures. Preliminary results of this intercomparison have been released by the referees and the NOAA FPH appears to have performed very well in terms of absolute calibration and stability.

A paper was published in 2014 that compares stratospheric water vapor data retrievals from the Aura Microwave Limb Sounder (MLS) with in situ water vapor measurements by the NOAA FPH at Boulder, Hilo and Lauder. The reference is:

Hurst, D. F., A. Lambert, W. G. Read, S. M. Davis, K. H. Rosenlof, E. G. Hall, A. F. Jordan, and S. J. Oltmans, Validation of Aura Microwave Limb Sounder stratospheric water vapor measurements by the NOAA frost point hygrometer, *J. Geophys. Res. Atmos.*, *119*, doi:10.1002/2013JD020757, 2014.

Dale Hurst (NOAA/CIRES) continues to serve as a member of the GRUAN working group, co-chair of the task team of site representatives and manager of the Boulder GRUAN site.

John Braun (NCAR) continues to serve as a member of the task team of GNSS-IPW measurements. Two previous members of this task team, June Wang (NCAR) and Seth Gutman (NOAA), have departed Boulder and are no longer asscociated with the Boulder GRUAN site.

James Hannigan (NCAR) is a member of the task team of ancillary measurements for his expertise in solar FTIR measurements of water vapor and trace gases.

Holger Vömel, now at NCAR, will serve on the task team for radiosondes.

WG-GRUAN interface

We appreciate the continued support of the Boulder GRUAN site through presentations and papers that include data from Boulder, especially those in easy view of ESRL management and NOAA administrators.

Items for ICM-7 plenary discussions

The Boulder GRUAN site manager has requested rapid feedback on the quality of each and every RS92 sounding performed at the site, so that deviations from standard operating procedures can be promptly detected and avoided. This idea was put forth to the GRUAN Lead Center last year, and in late 2014 the GRUAN site representatives were polled for their suggestion. It is hoped this topic can be specifically discussed at ICM-7 and a new RS92 data product (version 3) will include the capability to issue such rapid feedback.

Future plans

The Boulder site is attempting to continue all its GRUAN measurement programs after another year of flat federal funding.

GRUAN Station Report for Lauder

Reporting for the period Mar 2014 to Jan 2015
Date: 13-Jan-2015
Primary author: Richard Querel
(email: richard.querel@niwa.co.nz)

Overview

Lauder has received its official GRUAN certification for its RS92 measurement program. Lauder continues to launch ozonesondes (1 per week) and frost-point sondes (1 per month). GNSS data uploads to GRUAN have begun. All other systems (LIDARs, Microwave radiometers, UV/Vis and UV spectrometers, FTIR, TEI, surface radiation measurements, etc.) are operational and submitting regularly to NDACC, BSRN, WOUDC, TCCON and other partner networks.

Change and change management

Our principal sonde technician resigned June 2014 (after 10 years of service). A replacement technician started in October 2014. He has been trained on ozonesonde and frost-point sonde preparation and handling and data processing methods.

A new Ozonizer (ozonesonde conditioning and test unit) from DMT has been used since November 2014. Modestly lower ozonesonde background levels have been observed.

Resourcing

Lauder's GRUAN operations are partly funded through our Government-funded core research. The core funding for the GRUAN measurements has remained static since the last financial year; no change is anticipated for the coming (2015/2016) FY.

We receive GRUAN-specific funding from NOAA to support their frost-point hygrometer flights (sondes and consumables supplied by NOAA, staff time from NIWA's ozonesonde program).

NOAA funding also supports the alignment of our procedures and test equipment to GRUAN standards and requirements.

Site assessment and certification

In November 2014, Lauder received its official GRUAN certification for the RS-92 measurement program.

GRUAN related research

A PhD studentship funded by the German Academic Exchange Service (DAAD) will involve the creation of Site Atmospheric State Best Estimates (SASBE) of temperature, ozone and humidity profiles above the Lauder site using Lauder and GRUAN data. The student will be supervised by Peter Builtjes (Freie Universitaet Berlin), Greg Bodeker (Bodeker Scientific) and Richard Querel (NIWA).

WG-GRUAN interface

- What is the status of ozonesonde data homogenization across the GRUAN sites?

- What is the status of a standardized operating procedure and processing scheme for ozonesondes?
- What is the current state of usage/adoption of the RS41 in our community? Is a changeover from the RS92 planned?
- What is the status of the radiosonde co-location transfer function work?
-

Items for ICM-7 plenary discussions

See above in WG-GRUAN interface.

Future plans

We will continue with our ozonesonde and frost-point sonde measurements. We intend to compare our in-house processed ozonesonde output to the GRUAN products once available. We have uploaded one-day of GNSS data and the associated meta-data site log files to GRUAN as a test case and hope to begin the automatic uploading soon.

GRUAN Station Report for Lindenberg

Reporting for the period Mar 2014 to Jan 2015
Date: 4 February 2015
Primary author: Ruud Dirksen
(email:Ruud.Dirksen@dwd.de)

Overview

Lindenberg contributes to the RS92 and the GNSS data streams.

Potential GRUAN data products are: CFH, DFM09, COBALD, RS41.

Change and change management

Preparations for the RS92/RS41 transition: RS41 was tested in the laboratory, RS92/RS41 twin soundings.

A ground check was developed for the CFH.

Resourcing

The head of the Lead Centre resigned and left last October. The recruitment procedure is not finished yet.

Site assessment and certification

Not applicable, site is GRUAN certified since 2013.

GRUAN related research

The Lead Centre aims to be a knowledge base for radiosounding and as such harbours a wide variety of facilities to test and characterise radiosondes. These facilities are in principle available to everyone within the radiosounding community, and several co-operations have taken place at the Lindenberg facilities. The laboratory experiments focus on the characterisation of error sources such as radiation error, as well as calibration accuracy and time lag of RH sensors. Within this framework the following radiosonde types were investigated: RS92 & RS41 (Vaisala), DFM09 (GRAW), M10 (Modem), RS11 & iMS-100 (Meisei).

Intercomparisons between various radiosonde types are routinely performed:

- RS92/DFM09 on a weekly basis
- RS92/CFH/DFM09 on a bi-weekly basis
- COBALD instrument is flown once per month, together with CFH/RS92/DFM09

Furthermore, the Lead Centre participated in the MORGANE validation campaign at La Reunion, by assisting and training the local staff in the preparation and operation of a CFH.

GRUAN processing and archiving of RS92 data takes place at the Lead Centre.

GRUAN-related publications

Antón , M., D. Loyola, R. Roman, and H. Vömel, Validation of GOME-2/MetOp-A total water vapour column using reference radiosonde data from GRUAN network, Atmos. Meas. Tech. Discuss., 7(9), 9573–

9601, doi: 10.5194/amtd-7-9573-2014, 2014, URL http://www.atmos-meas-tech-discuss.net/7/9573/2014/.

Dirksen, R. J., et al., Reference quality upper-air measurements: GRUAN data processing for the Vaisala RS92 radiosonde, Atmos. Meas. Tech., 7(12), 4463–4490, doi:10.5194/amt-7-4463-2014, 2014.

WG-GRUAN interface

Not applicable.

Items for ICM-7 plenary discussions

New/other measurement techniques for reference measurements.

Future plans

Continuation of the existing intercomparison program.

Further investigation of the RS41 radiosonde, both in flight and in the laboratory.

Participating in the MORGANE campaign at La Reunion.

Development of the GRUAN dataprocessor version 3.

GRUAN Station Report for Ny-Alesund

Reporting for the period Mar 2014 to Jan 2015

Date: 23-Jan-2015

Primary author: Marion Maturilli

(email: marion.maturilli@awi.de)

Overview

The Ny-Ålesund dataflow for RS92 soundings is settled and certified, providing 1x daily radiosonde data to the GRUAN Lead Centre. During 6-25 September 2014, there has been an intensive radiosounding campaign at the station, with 4 launches per day.

In 2014, bi-monthly CFH launches have been established, providing profile data for

19 January, 19 March, 15 May, 5 July, 10 September, and 6 November 2014, as well as 21 January 2015. While the payload set-up and launch procedure are settled, we are aware that the CFH dataflow to the Lead Center needs to be improved.

The Ny-Ålesund GNSS station is one of two test sites to implement the GNSS dataflow in GRUAN. Ny-Ålesund GNSS data are now processed by GFZ without gaps since October 2014, and reprocessing of earlier data is ongoing. The GNSS data product transfer to the GRUAN Lead Centre (and NCDC) is in preparation.

Change and change management

Operators have changed with the arrival of the new overwintering team in April 2014. The new team has been introduced to GRUAN at the GRUAN Lead Centre in Lindenberg, and has adopted the GRUAN procedures on site in Ny-Ålesund .

Concerning the daily radiosondes, data are transferred to GTS in FULL BUFR since 29 Oct 2014.

We are not aware of any other relevant changes.

Resourcing

The financing of CFH launches currently depends on the annual scientific budget of our working group. By shifting these measurements to the long term monitoring program of the research base, the resource situation may become more stable. Defining CFH measurements a formal GRUAN data product will be helpful in this context.

Site assessment and certification

- already certified -

GRUAN related research

In June 2014, scientists of the MeteoMet project operated their mobile calibration unit at the AWIPEV research base in Ny-Ålesund, calibrating various sensors of surface meteorological equipment related to our GRUAN measurements.

Currently, we are working on the homogenization of the 22-year Ny-Ålesund radiosonde dataset. This includes GRUAN-processing of early RS92-rawdata by the GRUAN Lead Centre. A scientific publication of the Ny-Ålesund radiosonde climatology is planned, accompanied by the publication of a doi-referenced homogenized dataset.

Concerning GNSS, Ny-Ålesund data processing by GFZ is operational. The GRUAN product transfer to NCDC is in preparation by GFZ.

GRUAN-related publications:

- Musacchio C, Bellagarda S, Maturilli M, Graeser J, Vitale V, Merlone A (2014) Metrology Activities in Ny-Ålesund (Svalbard), submitted to *Meteorological Applications*
- Heinkelmann R, Dick G, Nilsson T, Soja B, Wickert J, Zus F, Schuh H (2015) Atmospheric gradients from GNSS, VLBI, and DORIS analyses and from Numerical Weather Models during CONT14. Abstract to EGU 2015: EGU2015-12670

WG-GRUAN interface

Eventually, promoting CFH measurements as important GRUAN product could help us in redefining the financial sources for CFH launches (see above).

Items for ICM-7 plenary discussions

- Time schedule for RS41 data stream and data product
- Requirements for change management RS92 → RS41

Future plans

- First (hardware) tests with RS41 and new Digicora software
- Potentially first period with multi-sensor launches (RS92 / RS41)
- Publication of homogenized Ny-Ålesund radiosonde dataset

GRUAN Station Report for Payerne

Reporting for the period Mar 2014 to Feb 2015

Date: 29-Jan-2015

Primary author: Rolf Philipona

email: rolf.philipona@meteoswiss.ch

Overview

The SRS-C34 radiosonde is in operation since January 2011. Measurements are taken UT00:00 and UT12:00. Data submission of the SRS-C34 GRUAN product using RsLaunchClient started 1 September 2014.

Vaisala RS92-SGP were launched in parallel with SRS-C34 twice per month, one flight during the night and one flight during the day. Data submission were made with RsLaunchClient for the two sondes per flight.

GNSS data are measured regularly since several years. We need information how to submit these data streams to GRUAN.

Lidar measurements are made. Data submission is in preparation.

Change and change management

The data format for SRS-C34 data submission to the Lead Centre has been developed in close collaboration with Michael Sommer from the Lead Centre. The mayor difference between the submission of a Meteolabor versus a Vaisala product is that the Meteolabor product does not only has the raw data as the Vaisala submission has. Instead, Payerne delivers for the SRS-C34 product the raw data, as well as the final calculated values and also includes the uncertainty value for each final calculated data point. Using the GRUAN RsLaunchClient we submit all meta data and the Payerne GRUAN data file to the lead Centre since 1 September 2014.

Starting 1 February 2015 we will launch weekly GRUAN multi-soundings with RS92, RS41 and SRS-C34 radiosondes. We will launch the multi-soundings alternatively one week during day-time and one week during night-time. Once per month the nigh-time sounding will additionally fly a SnowWhite/COBALD sensor for research purposes in collaboration with ETHZ. The multi-soundings will always be launched during standard operation times UTC00:00 and UTC12:00.

Resourcing

We had difficulties with manpower available for GRUAN activities. Therefore we had to reduce to two multi-soundings per week. Before January 2014 we had four flights per month and we will go back to four flights starting February 2015.

Site assessment and certification

End of October 2014 we send our GRUAN site-certification application to the Lead Centre. We received a response with many questions from the WG-GRUAN at the end of the year. We recently returned our answers to the questions of the WG-GRUAN. Basically we agree with the arguments of the WG-GRUAN and we agree that it is better for Payerne to first become GRUAN certified on the basis of weekly Vaisala soundings. We will then get a new Meteolabor radiosonde and in a second step Payerne will become GRUAN certified for the Meteolabor SRS-NEW radiosonde. In the mean time we will continue to submit our SRS-C34 GRUAN product to the lead Centre.

GRUAN related research

As CIMO-Testbed Payerne organised two radiosonde intercomparisons in June 2014, one week with MODEM, Meteolabor and Vaisala RS92 and one week with INTERMET, Meteolabor and Vaisala RS41 radiosondes. During these intercomparisons we always launched two sondes of each type together in order to investigate the reproducibility of the individual radiosondes. These intercomparisons allowed us determining the uncertainty for the Meteolabor radiosonde, and these uncertainty values are presently used in our SRS-C34 GRUAN product. However, since we are planning to introduce the SRS-NEW in the near future we will repeat some of these tests in 2015 and we will then publish the uncertainty values of the Meteolabor SRS-NEW radiosonde.

WG-GRUAN interface

The answers from the WG-GRUAN with regard to our station certification application were very helpful. The collaboration with the GRUAN Lead Centre with regard to a GRUAN product for the Meteolabor radiosonde is very good.

Items for ICM-7 plenary discussions

We should devote most of the time of the ICMs to the original goal of GRUAN, which is the improvement of radiosonde measurements for long-term upper-air climatology, and discuss results related to upper-air climate change monitoring and research.

Future plans

Our Goal is to become GRUAN certified during 2015 on the basis of weekly RS92 soundings. Meanwhile we continue flying daily SRS-C34 and deliver a GRUAN product for these flights (as we do since 1 September 2014). However, during 2015 we will also test a new Meteolabor radiosonde that is presently developed. Our aim is to replace the operational SRS-C34 by the new Meteolabor radiosonde SRS-NEW and deliver an improved daily GRUAN product starting early 2016. Change management will have to be made during 2016 and we hope we will then become GRUAN certified for the daily Meteolabor SRS-NEW radiosonde product.

GRUAN Station Report for Potenza

Reporting for the period Mar 2014 to Jan 2015

Date: 2015-01-31

Primary author: Fabio Madonna

(email: fabio.madonna@imaa.cnr.it)

Overview

Currently, only RS data are provided to the GRUAN archive. Aerosol, water vapor, clouds and radiation from lidar, GPS, ceilometers, and radiometers could be included in the future data streams. In particular GPS data stream could be immediately submitted to any GRUAN processing server.

Change and change management

SHC has been installed and tested. One launch each 15 days will be performed using the manual launcher (including the use of the SHC in the launch procedure), the other weekly launch will be performed with the autolauncher.

A new laboratory for the launch of radiosoundings is now operative.

Use of an inflation kit to fill in the balloon.

A second GPS mobile antenna is available for managing any possible change.

A sky camera is also now available.

A new pyranometer is available and it will be operational during this year.

Resourcing

Potenza is continuing to support GRUAN activities using not dedicated funds. Nevertheless the station is negotiating with the Met Service the possibility to transfer a RAOB Italian station to Potenza, adopting a one year transition period before the completion of the transfer.

Site assessment and certification

POTENZA applied for the certification in 2014. A response to the comments provided by the WG GRUAN will be provided by February, 10, 2015.

GRUAN related research

Comparison of water vapor Raman lidar profiles calibrated using difference water vapor measurements.

Madonna, F., Rosoldi, M., Güldner, J., Haefele, A., Kivi, R., Cadeddu, M. P., Sisterson, D., and Pappalardo, G.: Quantifying the value of redundant measurements at GCOS Reference Upper-Air Network sites, Atmos. Meas. Tech., 7, 3813-3823, doi:10.5194/amt-7-3813-2014, 2014. >

WG-GRUAN interface

The WMO/GCOS letter already drafted and agreed between the different parties should be finalized, it is still pending.

Items for ICM-7 plenary discussions

- Radiosonde scheduling for the stations performing one or two launches per week
- Establishment of other GRUAN products (GPS, Raman lidar, MWR)
- Use of collocation and redundancy studies to serve GRUAN community

Future plans

Dual launches involving the autosonde and the manual systems will be performed.

Negotiation with the Met Service about the possibility to transfer a RAOB Italian station to Potenza will continue and likely closed within 2015.

Every two months, an ozonesounding will be likely performed in 2015.

The water vapour Raman lidar will be upgraded to extend its maximum vertical range up to 10-12 km.

GRUAN Station Report for Sodankylä

Reporting for the period Mar 2014 to Jan 2015

Date: 31-Jan-2015

Primary author: Rigel Kivi (email:rigel.kivi@fmi.fi)

Overview

Sounding measurement programs are currently contributing to GRUAN data streams. At Sodankylä we have receiving systems for both manual and automated radiosoundings. Altogether 61 manual soundings and 722 autosonde launcher soundings have been submitted using the GRUAN operating procedures. The manual sounding dataflow includes Vaisala RS92-SGP, ECC ozone sonde, CFH water vapor, Intermet IMET-1, and Vaisala RS80. The data have been transmitted using the RsLaunchClient software. Preparations have been made to start the GNSS dataflow.

Change and change management

No major changes have taken place during the reporting period. RS92 and RS41 comparison flights were made at Sodankylä and at some other locations. RS41 showed improvements for humidity and temperature measurements compared to the RS92. In addition we were able to test the new interface for the RS41/ozonesonde flights. Also tests with the CFH reference were made.

Resourcing

Budget funding does not cover all the research activities, therefore external funding is needed to continue with these activities.

Site assessment and certification

Our site is not certified yet, we have submitted the application in late 2014. The review process is ongoing.

GRUAN related research

GRUAN research in our case is related to the GATNDOR and the Radiosonde task team.

WG-GRUAN interface

Letter of support would be useful.

Items for ICM-7 plenary discussions

Change management issues, for example in case of RS92/RS41. Also external funding possibilities would be of interest to discuss with the GRUAN partners. Finally, we are interested to include the GNSS dataflow.

Future plans

Over the coming year we expect to continue the site certification process, improve some of the instrumentation at the site and participate in the GRUAN task team activities.

GRUAN Station Report for Tateno

Reporting for the period Feb 2014 to Feb 2015

Date:14-Jan-2015

Primary author: Kohei Honda
(email:kohei_honda@met.kishou.go.jp)

Overview

The Tateno site operated by the Aerological Observatory of the Japan Meteorological Agency (JMA) conducts surface observation and low-layer wind observation up to 1.5 km by using a Doppler lidar, upper-atmosphere observation up to about 30 km by using radiosonde, ozone vertical distribution observation using ozonesondes, total column ozone observation using a Dobson ozone spectrophotometer, ultraviolet observation using a Brewer spectrophotometer and radiation observation. Among these observations, radiosonde sounding data are operationally provided to the GRUAN Lead Centre.

Change and change management

JMA started to use a new type of radiosonde “RS-11G” by Meisei in place of “RS92-SGP” by Vaisala at Tateno in 1 July 2013. These RS92-SGP and RS-11G radiosonde performed dual launch experiment in October to November 2013 and January 2014 to confirm consistency and to analyse difference as reported ICM-6. Continuously, Tateno performed the dual launch experiment in 10 to 25 March and 26 May to 30 June 2014.

In addition, the previous radiosonde (RS92-SGP) is launched alternately in 00Z and 12Z observation every Monday instead of RS-11G. Also, this RS92-SGP single launch event will be change to dual launch (+RS-11G) from this April.

Resourcing

(N/A)

Site assessment and certification

Tateno would like to apply for the GRUAN certification after the establishment of the data processing of RS-11G radiosonde.

GRUAN related research

(NA)

WG-GRUAN interface

(NA)

Items for ICM-7 plenary discussions

(N/A)

Future plans

Radiosonde procurement will continue determined by the competitive tendering process next year.

GRUAN GDP for Meisei radiosonde is currently creating. After completion of GRUAN GDP, Tateno will calculate the RAW data (JMAFMT) stored in the lead center.

Also, Tateno accept the other site data that use the RS-11G or iMS-100 radiosonde.

Appendix L: List of Participants

PARTICIPANT	CONTACT
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