WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR INSTRUMENTS
AND METHODS OF OBSERVATION

EXPERT TEAM ON NEW REMOTE SENSING TECHNOLOGIES (ET-NRST)

First Session

Geneva, Switzerland

22 to 25 August 2016

FINAL REPORT

DISCLAIMER

Regulation 43

Recommendations of working groups shall have no status within the Organization until they have been approved by the responsible constituent body. In the case of joint working groups the recommendations must be concurred with by the presidents of the constituent bodies concerned before being submitted to the designated constituent body.

Regulation 44

In the case of a recommendation made by a working group between sessions of the responsible constituent body, either in a session of a working group or by correspondence, the president of the body may, as an exceptional measure, approve the recommendation on behalf of the constituent body when the matter is, in his opinion, urgent, and does not appear to imply new obligations for Members. He may then submit this recommendation for adoption by the Executive Council or to the President of the Organization for action in accordance with Regulation 9(5).

Chairperson, Publications Board
World Meteorological Organization (WMO)
7 bis, avenue de la Paix
P.O. Box No. 2300
CH-1211 Geneva 2, Switzerland
Tel.: +41 (0)22 730 84 03
Fax: +41 (0)22 730 80 40
E-mail: Publications@wmo.int

NOTE:

The designations employed in WMO publications and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of WMO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Opinions expressed in WMO publications are those of the authors and do not necessarily reflect those of WMO. The mention of specific companies or products does not imply that they are endorsed or recommended by WMO in preference to others of a similar nature which are not mentioned or advertised.

This document (or report) is not an official publication of WMO and has not been subjected to its standard editorial procedures. The views expressed herein do not necessarily have the endorsement of the Organization.

CONTENTS

AGENDA

1. **ORGANIZATION OF THE SESSION**

   1.1 Opening of the Session
   1.2 Adoption of the Agenda
   1.3 Working Arrangements of the Session

2. **REVIEW OF TERMS OF REFERENCE AND WORK PLAN**

3. **RELEVANT OUTCOMES OF THE FOURTEENTH SESSION OF THE CIMO MANAGAMENT GROUP**

4. **FEASIBILITY OF CONDUCTING AN INTERNATIONAL INTERCOMPARISON OF TECHNIQUES FOR THE DETECTION OF AEROSOL/VOLCANIC ASH**

5. **PASSIVE MICROWAVE PROFILERS**

6. **ISO LIDAR STANDARDS**

7. **SOUTH AMERICAN LIDAR NETWORK**

8. **INTERACTION BETWEEN RELEVANT CIMO TESTBEDS AND ET-NRST**

9. **TRACEABILITY/UNCERTAINTY OF REMOTELY SENSED ATMOSPHERIC VERTICAL PROFILES**

10. **ANY OTHER BUSINESS**

    10.1 Improving the flow of information from the Testbeds to the CIMO community
    10.2 Update on different technologies
    10.3 Mm-wave radar for aerosol/volcanic ash detection
    10.4 Low cost water vapour lidar
    10.5 Competencies and training for aerosol lidar

11. **REVIEW AND REVISION OF WORK PLAN AND SCHEDULE**

12. **DRAFT REPORT OF THE SESSION**

13. **CLOSURE OF THE SESSION**

GENERAL SUMMARY

1. ORGANIZATION OF THE SESSION

1.1 Opening of the Session

1.1.1 The First Session of the CIMO Expert Team on New Remote Sensing Technologies (ET-NRST) was opened at 09:30 hours on Monday, 22 August 2016, at the WMO Secretariat, Geneva, Switzerland.

1.1.2 Dr Isabelle Rüedi, Head of the Instruments and Methods of Observation Unit of the Observing Systems Division, of the WMO Observing and Information Systems Department, warmly welcomed the participants (Annex I) to Geneva on behalf of the Secretary General of WMO. She informed the session that Dr Lidia Cucurull had recently tendered her resignation as Chair of the Expert Team, and that Mr Apituley, as Vice-Chair, had agreed at short notice to chair the session in her place. Dr Rüedi thanked Mr Apituley and apologized to the session for the uncertainty in regard to the organization of the meeting, which had been caused by the late change of venue and expressed her pleasure in seeing so many of the team present in Geneva. She thanked the team for its dedication to WMO and in particular in developing guidance material for WMO Members.

1.1.3 Dr Rüedi reminded the session that, in sharing their knowledge of best practice in the use of new remote sensing technologies by developing guidance material for WMO Members, all countries can benefit from the expertise of those who serve as experts under WIGOS. She stressed that it is these new technologies that will likely be the key to the future of WIGOS, so it is important to ensure that the material makes its way to the CIMO Guide. Dr Rüedi noted that the CIMO Guide focus is on operational systems, but that the IOM Report series can be used to share knowledge of pre-operation systems. Dr Rüedi informed the session that at the last CIMO Management Group meeting it was proposed to introduce a reporting mechanism, less rigorous than the requirements for an IOM Report, that could be used to more promptly share update information on developing systems. Dr Rüedi suggested that such a mechanism might help ET-NRST to get information on new technologies out to members countries as it becomes available.

1.1.4 Dr Rüedi described how the CIMO Testbeds and Lead Centres had been formed in recognition of the pockets of particular expertise that exists in certain technologies. But how can we better ensure the sharing of that knowledge? Dr Rüedi suggested that ET-NRST should take a lead role in this process. She noted that there are currently five Testbeds of relevance to ET-NRST: Lindenberg, Payerne, Izaña, Hohenpeissenberg and Cabauw and that one of the agenda items for discussion during the current session concerns how to best strengthen the flow of information from these Testbeds to WMO Members. How can the Testbeds themselves help, perhaps by organizing specific activities? And how should the expert team best link with other groups, such as GRUAN?

1.1.5 Dr Rüedi concluded that the current session would involve some discussion, and some work on guidance material already developed by the expert team group. She expressed hope that the team capitalises on the opportunity for some undisturbed time during the week to progress the tasks in its work plan and asked all participants to support Mr Apituley to adapt to his new role in chairing the session.

1.2 Adoption of the Agenda

The provisional agenda was adopted by the session after some adjustment to take into account a number of suggestions from the membership.

1.3 Working Arrangements of the Session

The Meeting agreed on details concerning the organization of its work, including working hours. The Chair reminded the session that the meeting and its documents were in English only.

2. REVIEW OF TERMS OF REFERENCE AND WORK PLAN

Mr Apituley informed the session that he would not provide a Chair's report, per se. He suggested that instead of the Chair's report, round table introductions from those present (see Annex I) would be worthwhile, since this was the first face-to-face meeting of the team, followed by review of the Terms of Reference and Work Plan of the team, to remind the participants of the topics under its responsibility. It was noted that the Work Plan of the expert team is derived almost exclusively from its Terms of Reference and addresses each of them, except, notably, that which addresses training, for which nothing is currently included in the Work Plan. Mr Apituley suggested that the session may later wish to consider adding a task in the Work Plan to deal with this shortcoming.

3. RELEVANT OUTCOMES OF THE FOURTEENTH SESSION OF THE CIMO MANAGAMENT GROUP

3.1 Dr Rüedi summarised the relevant outcomes of the Fourteenth Session of the CIMO Management Group (CIMO MG-14), held from 5 to 8 April 2016, in Offenbach, Germany.

3.2 There had been some discussion within WMO in recent times of revising the terms of reference and structure of the technical commissions (possibly at Cg-18). CIMO MG-14 addressed this potential development by closely examining its role throughout the history of WMO to extract the essence of the commission: in the event that CIMO ceased to exist as an individual technical commission, what is the essence of CIMO that must be retained in an future WMO structure? The conclusion of CIMO MG-14 was that under any circumstances, it would be essential to retain CIMO's instrumentation and observations expertise, the capacity for provision of guidance on best practice in regard to instrumentation and methods of observation, increasingly focusing on 3rd party data, crowd sourcing, etc., and the ability to provide advice to Members on how a particular data type can and cannot be used.

3.3 CIMO MG-14 considered a proposal, originally stemming from the CIMO/WIGOS Exploratory Workshop: Improving Surface-based Data Quality through Improved Standardization of Procedures (3-5 December 2014, Langen, Germany) and later endorsed by Cg-17, to merge part of ET-ORST and CBS ET-SBO to form a CIMO led Inter-Programme Expert Team on Operational Weather Radars (IPET-OWR). Dr Rüedi informed the session the CIMO MG-14 had supported the proposal, it had been subsequently approved at EC-68 and the membership of the new team was being selected.

3.4 CIMO MG-14 discussed the topic of international instrument intercomparisons. It had noted that SPICE is in its concluding stages, with the final report expected later in 2016. RQQI, which had fallen into stasis between 2013 and 2015 is being reinvigorated and restarted, with a view to its completion in 2017. Hence, CIMO is ready to embark upon a new intercomparison, with perhaps a second commencing in 2017. Hence two feasibility studies are underway regarding a potential international intercomparison of upper air observing techniques (radiosondes, etc.) and a potential intercomparison of technologies for detection of aerosol and volcanic ash. Each of these studies is still underway so no decision has yet been made by CIMO MG on whether either intercomparison should go ahead.

3.5 CIMO MG-14 was informed that ISO has proposed that a new international standard be developed on continuous wave wind lidars: a companion standard to that being concluded by ISO TC146/SC5/WG6 on pulsed heterodyne Doppler wind lidars. CIMO MG-14 discussed whether WMO should partner with ISO on the development of this latest standard, concluding that it probably should and that the standard should be developed as a joint WMO/ISO standard.

4. FEASIBILITY OF CONDUCTING AN INTERNATIONAL INTERCOMPARISON OF TECHNIQUES FOR THE DETECTION OF AEROSOL/VOLCANIC ASH

4.1 The leader of the ad hoc working group addressing this matter, Dr Philippe Keckhut, was unable to attend the session to brief the members on the progress of the working group, so Mr Apituley, a member of the working group, provided a brief summary on Dr Keckhut's behalf. It was noted that the ad hoc working group is not carrying out the feasibility study at this stage, but preparing the way for it by examining the capabilities of aerosol lidars for volcanic ash detection. Once this preliminary study has been completed, a smaller, multi-technology task team will be formed to examine the feasibility of conducting an international intercomparison of detection techniques.

4.2 Mr Apituley informed the session that the ad hoc working group comprised experts on lidar technology from ET-NRST and others from the lidar community. It had commenced its work by first examining the requirements for volcanic ash detection, typing and quantification and the key lidar parameters to be considered in determining a lidar's capabilities in this regard. The range of lidar techniques that are used was next examined, and which are available for quantifying volcanic ash. The group then examined reports of previous intercomparisons to identify the strengths and weaknesses of each (lessons learned). All of the above is being summarized in a draft report.

4.3 At its most recent meeting in May 2016, the working group examined the draft report, proposed some structural changes. Those changes have now been made and the report is being finalized. On completion it will be submitted to ET-NRST for consideration.

4.4 In discussion the session agreed that if an intercomparison is ultimately to go ahead a well characterized instrument will be needed as a reference. It was noted, too, that it will not be possible to wait for a particular volcano to erupt but instead it would most likely be necessary to make use of a proxy for volcanic ash, such as Saharan dust and to locate the experiment somewhere where airborne dust is commonly observed.

4.5 It was noted that the current ad hoc working group has been referring to itself as an expert team, but that it is not an expert team in the recognized sense of the term. It was also noted that there would be a need for the task team, once it is formed, to include in its consideration alternative observing technologies for volcanic ash detection, in addition to lidar. Finally, it was noted that completion of the feasibility study is an urgent requirement, now that SPICE is almost complete and there is the capacity to commence a new CIMO international intercomparison.

5. PASSIVE MICROWAVE PROFILERS

5.1 Prof PW Chan presented the latest draft of a proposed IOM report on microwave profilers (MWP). The document was originally drafted by the forerunner of ET-NRST, the Expert Team on New Technologies and Testbeds. That team had considered that the draft document needed further expansion to include additional aspects of the technique, in particular an analysis of the uncertainties of MWP measurements, height resolution estimation and how these estimates are obtained. Prof Chan informed the session of the results of his initial survey of members operating MWP and his use of the information obtained and other published documentation to address each of the points made by the previous ET in the latest draft. The updated draft includes new text on domes, measurement uncertainties, vertical resolution, height estimation (which he noted is difficult with this technology), satellite channels, the transmittance equations and the retrieval method. He noted that most of the remainder of the document was unchanged. He suggested that it is generally biased towards Russian MWP models, so is somewhat propriety and suggested it should be made more globally representative by including consideration of other MWP models, or by removing the information related to particular models.

5.2 Prof Chan also presented a draft updated contribution to the CIMO Guide on MWP, which had recently benefited from review suggestions from the Payerne Testbed. He noted that he had made similar changes to the existing text of the CIMO Guide as he had done to the draft IOM, but focused on high level discussion of the technique rather than including equations. It now included some text on use of data, retrieval method and applications method.

5.3 In discussing how to progress the two documents it was agreed that the current material in the CIMO Guide is in need of revision and update, because MWPs are now entering operation in a number of countries and Members need up-to-date guidance material on this technology. It was agreed that the current bias towards particular manufacturers needs to be eliminated and that further information on siting, scan strategy and calibration intervals could be added. It was suggested that much of this is addressed in the COST TOPROF documentation and some of that information might be added to the CIMO Guide material. Dr Haefele agreed to follow up this aspect. The session was informed that the MWP material should ideally be finalized by early 2017 in the case of the CIMO Guide update, and late 2017 in the case of the IOM report.

6. ISO LIDAR STANDARDS

6.1 Mr Apituley briefed the session on the progress achieved within ISO TC146/SC5/WG6 on development of a WMO/ISO standard (Part 2) on pulsed heterodyne Doppler wind lidars, and on the initial stages of development of a companion standard (Part 3) on continuous wave wind lidars.

6.2 With regard to Part 2, Mr Apituley informed the session that the initial draft stemmed from a French document and the initial chair of the working group, who has since resigned, was French. He noted that it is a small group working on the standard so the draft was strongly biased towards French needs. It is now under wider review and has been circulated amongst lidar experts in the WMO community, who have made some suggestions regarding the need for improvements to the document. It is expected that the standard will be finalized over the coming months and most likely published before the end of 2016 as the second joint WMO/ISO standard.

6.3 Part 3, on continuous wave wind lidars, will be based on an initial British draft. It is to deal with operation, maintenance and calibration of these lidars. Development of the standard is expected to take place during 2017.

6.4 Discussion followed on how the need to keep draft ISO material in confidence until the public review stage has hampered provision of broad WMO input into the preparation of these documents, and how we need to liaise with ISO on how to better coordinate this process in future. With regard to Part 3 of the wind lidar standard, Dr Cuevas agreed to consult with colleagues then suggest experts to join WG6 for the development of this standard.

7. SOUTH AMERICAN LIDAR NETWORK

7.1 Dr Ristori presented a draft report on the Argentinian lidar network. He informed the session that, while at the outset he had aimed to develop a document on instruments and methods of observation of aerosol and volcanic ash, he discovered a wide range of instruments is used for this purpose, so decided to focus his efforts on producing a comprehensive report on the use of lidars.

7.2 He described the construction and deployment of the Argentinian lidar network. The instruments have been designed for trouble-free operation in remote locations. He noted that they are not eye-safe, but are located in no-fly zones for helicopters and are no threat to aircraft at altitude. He noted that a future addition will be an auto-switch-off if aircraft are detected by radar in the vicinity. Another feature of the instrument design is their suitability for operation by trained technicians rather than research scientists and all components have been manufactured in their own workshop, decreasing dependence on purchase of components externally.

7.3 The Latin American Lidar Network (LALINET) currently comprises 12 lidars across South America, with 6 in Argentina. It comprises a collaboration with JICA and JST. The next scheduled installation will be at Punta Arenas.

7.4 Dr Ristori noted that the aim of LALINET is research, whereas for SAVER.net the aim is operations with a secondary aim of research. He informed the session that there is some potential for using one or more of the LALINET sites for testing the feasibility of conducting an intercomparison of techniques for volcanic ash detection.

7.5 Dr Ristori requested comments from the session on his draft report and suggestions as to what should and should not be included in the next draft of the IOM report. It was noted that an IOM report enables flexibility in this regard: it is largely up to the author to decide what to include and what to omit, although as the name suggests, the focus should be on instruments and methods of operation. Hence a report on aerosol lidars probably should focus on the technology used and the role of each component, the operational principles, technique and practices, the maintenance requirements and instrument calibration. The design features of suitability for remote operation and operation by technicians rather than research scientists could be stressed, and training requirements, sample data analyses and networks details would be useful. It was noted that the existing draft goes a long way towards satisfying these requirements.

7.6 Mr Apituley agreed to provide a detailed review of the document for Dr Ristori before the end of September so that the report could be refined and completed for submission to the CIMO Editorial Board by the end of 2016.

8. INTERACTION BETWEEN RELEVANT CIMO TESTBEDS AND ET-NRST

8.1 Mr Apituley informed the session that CIMO Testbeds are seen as centres of excellence for developing, trialing, testing and characterizing new observing technologies and how it is intended that through close liaison between the Lindenberg, Hohenpeissenberg, Payerne, Izaña, and most recently Cabauw, Testbeds and ET-NRST, the knowledge gained by those Testbeds can be transferred to the expert team for it to convert the Testbed outcomes into improved guidance material for WMO Members on these technologies (for example, through the development of IOM reports and draft material for updates to the CIMO Guide). He noted, however, that the most effective mechanism for ensuring this knowledge dissemination still needs to be developed and that the current session had been requested to explore this issue.

8.2 Mr Apituley noted that the participants of the current section had been selected to include both the members of ET-NRST and representatives from each of the relevant Testbeds. To remind the expert team members of the work of the Testbeds, he suggested that the Testbeds representatives first report briefly on the achievements of their respective Testbed over recent months, and on work currently underway. He requested them to advise the session on those aspects that they see as being most mature and relevant for other Members' operations to pave the way for the session to discuss potential mechanisms that can be established to better achieve the flow of information from the Testbeds to WMO Members via the expert team.

Lindenberg

8.3 Dr Frank Beyrich, participating via webex from Lindenberg with Dr Volker Lehmann (Chair, ET-ORST) and Dr Ruud Dirksen (GRUAN Lead Centre) described the Lindenberg Testbed and its programme. He noted that Lindenberg comprises a CIMO remote sensing Testbed, a CIMO Lead Centre on Process-Oriented Studies, and also the GRUAN Lead Centre, so brings together in-situ and remote-sensing sounding systems plus research into boundary layer and radiation processes. He briefly described the instruments and experiments underway at Lindenberg.

8.4 Dr Beyrich highlighted the work currently underway in intercomparing lidar wind profilers with their 482 MHz radar wind profiler (0.5 km to 6 km) and with tower (60 m to 100 m) and sodar (60 m to 500 m). He noted that one year of intercomparison between lidar, sodar and tower data showed excellent agreement between tower and lidar data, but less agreement with the sodar data, partly due to a 500 m site separation and some influences from forest patches on the sodar wind measurements for certain wind directions.

8.5 He described an intercomparison of ceilometers (Ceilinex-2015) to enable examination of the differences in performance between the same models and different models (six in all, including Lufft, Campbell and Vaisala). This experiment involves evaluation of different calibration methods used for the ceilometers and a comparison of cloud base height which has revealed consistent differences of up to 70 m for low-level liquid-water clouds, but up to several kilometres for thin ice clouds, significant differences in the shape of backscatter profiles and different definitions of cloud base height being used by different instruments. He noted that the same types of instrument tend to produce similar results.

8.6 Dr Beyrich described recent tests performed on a commercial prototype DIAL water vapour lidar (Vaisala), which proved to be easy to deploy and fully autonomous, with no principal calibration issues since it uses the DIAL technique. It is suitable for 24/7 all-weather operation, though the data, naturally, have limited availability in and above optically thick clouds. This lidar is expected to be commercially available within 2-3 years.

8.7 He described additional experiments with scintillometers, different techniques for cloud cover detection (nubiscope, camera, etc.,) and further work with heterodyne lidars.

8.8 Dr Beyrich briefly described the work being performed within the GRUAN Lead Centre, including the recruitment of new GRUAN stations and RS92-RS41 change management, experiments with new infrastructure (RAMSES, lidars, spectrometers) and Lindenberg plans for further testing of surface based radio-sounding systems, wind lidars, photometers for aerosol optical depth and integrated water vapour, turbulence (IR Doppler radars) and the detection and quantification of low clouds.

8.9 Dr Beyrich concluded by noting that much of the work performed at Lindenberg is premature for developing guidance material for WMO Members, but that completed work will be presented at TECO 2016, at which point it will be possible to discuss how best to feed the information into CIMO guidance material.

Payerne

8.10 Dr Alexander Haefele, representing Mr Dominique Ruffieux, described the Payerne Testbed and the numerous technologies deployed there. He noted the importance of the Payerne profilers for nuclear power plant monitoring. He described the work recently completed or underway with various remote sensing technologies, including Raman lidar for water vapour, temperature and aerosol profile measurement, low cost lidars for aerosol and volcanic ash detection, operational microwave profilers, investigation of optimal estimation techniques for data retrieval, data assimilation for NWP, radiofrequency protection activities and metrology for remote sensing techniques.

8.11 Dr Haefele informed the session that the work at Payerne has led to the conclusion that the water vapour Raman lidar has reached the level of maturity (scientific knowledge, technical solutions) for transition to operations. The result of the major collaborative effort carried out under E-PROFILE and TOPROF has been achievement of a very good understanding of the performance and capabilities of low cost automatic backscatter lidars (traditionally referred to as ceilometers), together with the establishment of a software suite that allows derivation of profiles of attenuated backscatter coefficient in an automatic manner. The high number of instruments combined with their robustness and, though limited, capability to do aerosol profiling makes the ceilometer an important component in the observing system of volcanic ash.

8.12 Regarding potential guidance material for CIMO Members (WIGOS guidance material), Dr Haefele suggested that the GRUAN lidar and MWP Guide, the TOPROF recommendation for MWP operation, the E-PROFILE recommendations for ceilometer operation and the standardization of representation of vertical resolution and uncertainty for NDACC lidars is each a source of material that could be used as the basis for development of improved guidance material for CIMO Members.

Izaña

8.13 Dr Cuevas described the Izaña Testbed, noting that it had been approved as a new CIMO Testbed for Aerosols and Water Vapour Remote Sensing Instruments in 2014 at CIMO-16. He informed the session of three activities that had been recently completed.

8.14 The first has involved development of a new methodology to derive AOD from Izana's Mark-I potassium-based resonant scattering spectrometer, enabling the recovery of an AOD long term series (37 years), that can be considered as one of the longest existing high-accuracy AOD records in the world. At the same time, Izaña has performed an investigation into techniques for performing night-time AOD and column water vapour measurements. Several lunar photometer prototypes have been tested in collaboration with Cimel Electronique, leading to the development of a final version, the CE318-T, which can perform day and night time photometric measurements using the sun and the moon as light sources, respectively. The quantitative uncertainty of the AOD measurements has been determined and the instrument has recently been adopted by AERONET as its network standard.

8.15 The reconstruction of a 73-year time series of AOD at 500 nm at Izaña has been performed by using artificial neural networks (ANNs) from 1941 to 2001 and AOD measurements directly obtained with a Precision Filter Radiometer (PFR) between 2003 and 2013. The ANN AOD time series has been comprehensively validated against coincident AOD measurements performed with the Mark-I spectrometer (1984–2009) and AERONET Cimel photometers (2004–2009), to obtain a good agreement. This method has proved to be a very useful tool to obtain daily AOD_500 values from meteorological input data, such as the horizontal visibility, fraction of clear sky, and relative humidity recorded at the Izaña Testbed. The methodology could be extrapolated to other sites, especially those affected by high dust loads.

8.16 The third activity has been the development of methodologies for vertical profiling of HDO/H216O, and corresponding validation and comparison with in-situ airborne and ground-based observations during the MUSICA (investigating the Cycle of Atmospheric water) remote sensing validation campaign in 2014 and 2105. The results of this project will contribute to a better understanding of the different processes affecting the cycle of atmospheric water and its link to the global energy balance.

8.17 Current and future activities at Izaña Testbed are aimed at the development and improvement of new techniques and methodologies for AOD determination, with a focus on mineral dust aerosol. Work will continue on improving the quality of nocturnal AOD observations, on intercomparing and establishing traceability between AERONET AOD measurements and those from the GAW Precision Filter Radiometer (PFR) Network of PMOD-WRC and also the Cimel standards. A new zenith looking narrow-band radiometer system (ZEN) for dust AOD monitoring has been developed and implemented at the Izaña Testbed and investigation into the performance of this instrument will continue, and investigation into the use of the Brewer spectrophotometer for operational AOD retrieval will continue.

8.18 In conclusion, Dr Cuevas noted that the Izaña Testbed is ideally located and equipped for the evaluation of new techniques and technologies for measurement of water vapour and atmospheric aerosol, particularly mineral dust, hence for assessing the performance of remote sensing instruments for volcanic aerosol detection.

Cabauw

8.19 Mr Apituley briefly described the most recent addition to the CIMO Testbeds, at Cabauw. He described its 220 m instrumented tower and the instrumentation located at the nearby remote sensing site.

8.20 Recent and ongoing activities at Cabauw using its broad suite of instrumentation include volcanic ash detection (using depolarization radar), boundary layer height determination, satellite validation, aerosol measurement (using mobile phones), RS92-RS41 investigation including ground check unit for full humidity range checking, aerosol layer height, and a soon-to-commence NO_2 instrument intercomparison campaign in the framework of satellite validation. All these activities will be described in the site document being prepared for posting on the CIMO website with the other Testbed site documents.

Improving the flow of information from Testbeds to the CIMO community via ET-NRST

The session discussed potential mechanisms for improving the flow of information from the Testbeds to the expert team and conversion of the results of the Testbeds' leading edge research into guidance for Members on operational use of remote sensing technologies for observations. A number of potential mechanisms was identified:

- Each Testbed, through its Testbed focal point, to send papers, once published, to the ET chair, for distribution amongst the ET members (push method). Use of the material in preparation of guidance material for Members could then be factored into the ET Work Plan.

- The ET member tasked with Testbed liaison to scan the Testbed annual reports for publications and request the Testbed's focal point to send copies to the ET for consideration (pull method).
- Testbed representatives to continue to participate in ET teleconferences.
- Invite one Testbed's focal point per teleconference, on a rotating basis, to provide a presentation on the Testbed's recent achievements and work in progress, for ET discussion on potential for development of improved guidance material based on the work.

8.21 The session agreed that to ensure the best chance of a workable and sustainable mechanism, responsibility should lie primarily with the ET, rather than the Testbeds, to minimize the additional burden on the Testbeds, whose primary focus is research. Hence the pull method is likely to be more effective than the push method.

9. TRACEABILITY/UNCERTAINTY OF REMOTELY SENSED ATMOSPHERIC VERTICAL PROFILES

9.1 Dr de Haan briefed the session on the initial progress he had made on documenting the traceability and quantitative uncertainty of remotely sensed atmospheric vertical profiles. It had been previously agreed by the expert team to focus initially on GNSS-derived data, as a first step, since this was considered a tractable problem, whereas establishing the traceability and quantifying the uncertainty of data from other remote sensing techniques were likely to present a more difficult task.

9.2 Dr de Haan first clarified the definition and meaning of traceability as the establishment and maintenance of a documented unbroken chain of links to an agreed standard, with all uncertainties being quantified. He then ran through the GNSS processing chain for zenith total delay (ZTD) and integrated water vapour (IWV) and used previously published documentation on GNSS uncertainties to explore the traceability chain for GNSS.

9.3 Dr de Haan thanked Dr Sakai for providing comments on the document from JMA, and requested additional feedback from the expert team regarding the appropriateness of his approach, and any suggestions on how he should continue. The session agreed that Dr de Haan's approach was good and that he should continue his current approach. It was noted that a potential future change to the membership of the expert team may see the recruitment of another GNSS expert who might be able to assist Dr de Haan with this task. Attention was also drawn to the work in progress under GRUAN (by Thierry LeBlanc (JPL, USA)) to develop a technical document on lidar observations which would include an analysis of data traceability and uncertainties and that Dr de Haan might draw on this work, once available, in progressing his task. It was noted that several other international efforts (e.g. GAIA-CLIM) are currently underway to characterise GNSS measurements and that published results of these efforts may assist in the preparation of guidance material for CIMO Members.

9.4 The session agreed that the best way forward with this task would be for Dr de Haan to continue with his initial approach, and to establish contact with the GRUAN and GAIA-CLIM efforts to explore the potential for utilizing the results of these investigations, once published, to strengthen the draft CIMO guidance material.

10. ANY OTHER BUSINESS

The session considered several additional items raised at the start of the meeting.

10.1 Improving the flow of information from the Testbeds to the CIMO community

10.1.1 Mr Apituley described an issue raised at CIMO MG-14 concerning the need for a new fast-track mechanism for making new guidance information available to Members. The CIMO Management Group had discussed the long lead times required for approval of updates to the

CIMO Guide and other WMO regulatory and guidance material, and faster but still lengthy timelines required for publication of IOM reports despite best efforts in the WMO secretariat to minimize these timelines. It had requested the expert teams to consider this issue and propose a fast track mechanism whereby new guidance material could be brought to the attention of members more promptly.

10.1.2 Mr Apituley noted that this fast track mechanism was seen to be needed, not for CIMO Guide contributions nor for reports of the length, detail or scientific rigour of IOM reports, but for shorter contributions on new developments, with a rapid publication timeline of weeks rather than months.

10.1.3 The session agreed that such a mechanism would be very useful. It suggested that such contributions could be reviewed by selected ET members, where the required expertise existed within the ET, or else by a few suitable external reviewers, that such contributions might only be of a few pages in length, and could be published directly on the CIMO website. They might be referred to as CIMO Technical Notes and a template could be placed on the website for easy access.

10.2 Update on different technologies

10.2.1 Addressing Task 4 in the ET-NRST Work Plan, Mr Apituley asked those present to provide brief updates on any progress on their assigned technologies.

10.2.2 Mr Apituley commenced by noting that, with regard to ceilometers, technological developments are underway by Lufft to include depolarization measurements in ceilometers to improve ash detection. Dr Haefele informed the session of the development underway of low cost lidars: Micro Pulse Lidar MPL, automatic back-scatter lidar (the ‘sharp end’ of ceilometer technology). Dr Ristori noted the development of a new Ever Rise laser ceilometer and an interferometer, and recent testing of a Raman temperature lidar. He also informed the session that NIES (Japan) and CEILAP (Argentina) are working on daytime straightforward detection of the aerosol extinction profile by means of the high spectral resolution backscatter structure of a multimode (unseeded) lidar. Each group is utilizing a different approach but each has an interferometer matching the free spectral range of the laser longitudinal modes.

10.2.3 Dr Cuevas noted the development by Siemens of a 500 and 800 nm depolarisation lidar system (4 channels), currently in prototype only, that will soon be tested at Izaña.

10.2.4 With regard to low cost water vapour lidars, it was reported that work is underway at JMA (see Section 10.4 below) and at Vaisala to develop and test new devices for the market.

10.2.5 Mr de Haan noted that GNSS slant observations are becoming more common (signal between satellite and receiver).

10.2.6 Finally, mention was made of the development currently underway of an onboard aircraft infrared scanner intended to warn pilots of ash clouds ahead.

10.2.7 It was noted that all present at the meeting expected to participate at TECO 2016 in Madrid and would use the opportunity of the World Meteorological Technology Expo 2016 to investigate the latest commercially available instruments.

10.3 Mm-wave radar for aerosol/volcanic ash detection

10.3.1 Dr Clain provided a brief presentation on behalf of HMEI on the development of the BASTA cloud radar, a mm-wave radar with some potential for aerosol-volcanic ash detection. The radar was developed by LATMOS, and one has been installed at Darwin since 2014. It operates at 95 GHz (3.2 mm) and is a 1 W FM (chirper) continuous wave radar with a 0.5-1.0 s integration time, 0.4 degree beamwidth. It can be operated in different range modes: 12 km (10 m/s unambiguous velocity) to 24 km (2.5 m/s). The radar is small (1.5 x 0.94 x 0.74 m) and lightweight (70 kg).

10.3.2 A mobile version is also available, which is smaller (82 x 46 x 45 cm) and more portable (35 kg). This mobile version was used together with a 24 GHz Metek Micro Rain Doppler Radar (MRR, 1.2 cm) and a 23.5 cm VOLDORAD Doppler radar in an experiment focusing on the Mt Etna plume to demonstrate potential for aerosol / volcanic ash detection.

10.3.3 The results of the experiment have been published in two papers by F. Donnadieur et al., and the radar principle is detailed in Delanoë et al.:

- Donnadieu F. (2012). Volcanological Applications of Doppler Radars: A Review and Examples from a Transportable Pulse Radar in L-Band. In: J Bech and JL Chau (eds.)Doppler Radar Observations - Weather Radar, Wind Profiler, Ionospheric Radar, and Other Advanced Applications. pp. doi:10.5772/35940. InTech.

- Donnadieu F., Freville P., Hervier C., Coltelli M., Scollo S., Prestifilippo M., Valade S., Rivet S., Cacault P. (2016). Near-source Doppler radar monitoring of tephra plumes at Etna. *Journal of Volcanology and Geothermal Research* vol.312, p.26-39, doi:10.1016/j.jvolgeores.2016.01.009.

- Delanoë J., Protat A., Vinson J.-P., Brett W., Caudoux C., Bertrand F., Parent du Châtelet J., Hallali R., Barthès L., Haeffelin M., Dupont J.-C. et al., *BASTA: A 95-GHz FMCW Doppler radar for cloud and fog studies, Journal of Atmospheric and Oceanic Technology*, American Meteorological Society, 2016, 33 (5), pp.1023-1038.

10.4 Low cost water vapour lidar

10.4.1 Dr Sakai next provided a brief presentation on the development and testing of mobile and compact water vapour lidars at Meteorological Research Institute (MRI), (Raman and DIAL), the main aim of which is to provide an instrument for measuring the H_2O distribution upwind of Cu/Cb development to improve model prediction.

10.4.2 The strengths of the Raman system are that it is simple and easy to operate. Its disadvantages are that it is difficult to obtain night-time data and it needs calibration. It is mounted in a trailer and weighs 200 kg altogether.

10.4.3 In the case of the DIAL lidar, it is self-calibrating, but tuning and stabilizing can be difficult and it has an eye safety issue.

10.4.4 The DIAL lidar operates at 829 nm and is much smaller than the Raman, but its repetition rate is much higher. Power times telescope size is much smaller (4 mW vs 2 W for Raman). Total mass is 100 kg. The DIAL lidar produces a 1 hour averaged profile, so the temporal resolution of the profiles is much coarser than the Raman. In order to improve daytime performance, an increase of laser power may be needed.

10.4.5 During the experiment, twice daily radiosonde flights are conducted. One per week is used for calibration of the system, the remainder for verification of the lidar data.

10.4.6 Purchase and operational costs of the two lidars are similar: 130k USD for purchase of the Raman components, 150k USD for the DIAL (material costs only). Running costs are around 2k USD per month for each. Raman only needs attention to replace failed components, but the DIAL probably has a lower maintenance cost, time-wise.

10.4.7 It was noted that for daytime operation (the key period for which information is required) MWPs can have advantages, but suffer from lower vertical resolution and higher purchase costs (300k USD).

10.4.8 The chair thanked Dr Sakai for his presentation and noted that, in view of the particular expertise in the expert team, there may be scope for adding an task to the Work Plan on integrating water vapour observations from different technologies.

10.5 Competencies and training for aerosol lidar

10.5.1 In discussion during the session, Dr Ristori and Dr Haefele had agreed to meet out of session to discuss the need for and scope for development of a competency framework for those involved with aerosol lidar operation and data use and the implications for training of those staff. Dr Haefele provided a brief presentation to the session on the outcome of that initial discussion.

10.5.2 Dr Haefele noted that the operation of and use of the data from complex observing equipment involves four groups of people: the users of the measurements (forecaster, NWP, VAAC, airlines), the operators of the equipment (observer, technician, engineer), the technical experts with oversight of the observing equipment and programme, and the applications experts with oversight of the systems that utilize the output measurements from the observing system for the provision of meteorological services to the community. He suggested that observing instrumentation can only be considered operational if it is supported exclusively by the user and the operator.

10.5.3 The experts define the competencies needed to operate the equipment and use its measurements and may be research scientists working within the organization that owns the observing equipment or application systems, or the providers of the equipment or systems.

10.5.4 Once the required competencies of each group have been identified and documented, they can then be provided to trainers to assist in the development of training curricula for the respective staff.

10.5.5 Competency requirements identified as being particularly important in the case of complex observing equipment were performance monitoring and provision of feedback (from data users) to instrument technicians to advise of potential problems as evidenced by suspect data. Ensuring that difficult issues (where there is nothing apparently wrong with the device) that can be corrected should also be included.

10.5.6 A simple approach to addressing these matters is to consider first who the user is and what the user needs to understand about the instrument and its measurements to correctly perform their job. Similarly, who is the operator and what do these people need to understand to operate the instrumentation, noting that they may not be located on-site? The complexity of the observing technology and the applications that use the measurements will likely determine the extent to which the four different groups need to overlap in capabilities.

10.5.7 Dr Haefele and Dr Ristori noted in conclusion that their discussion had been too brief to make further progress, but that they would continue to pursue the topic after the session, to develop a competency framework for a lidar network that enables full transition of the network to operational mode. It was suggested that Part II, Chapter 3, Section 3.1.5 of WMO Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology (WMO No. 1083) might be used as the basis for developing competencies for lidar observers and technicians, and that the four draft competency frameworks recently developed within CIMO TT-Competencies may also be useful.

11. REVIEW AND REVISION OF WORK PLAN AND SCHEDULE

The session reviewed and revised its Work Plan and schedule for the remainder of the CIMO intersessional period, in the light of the team's discussion during the session (Annex II).

12. DRAFT REPORT OF THE SESSION

The meeting agreed on arrangements for finalisation of the draft report of the session.

13. CLOSURE OF THE SESSION

The session was closed at 16:00 on Thursday 25 August.

ANNEX I

LIST OF PARTICIPANTS

Mr Arnoud APITULEY ***Chair***	Royal Netherlands Meteorological Institute Utrechtsweg 297 3731 GA de Bilt The Netherlands Tel: +31302206418 apituley@knmi.nl
Dr Pablo RISTORI	Laser and Applications Centre – Lidar Division Ciudad Autonoma de Buenos Aires Argentina Tel : +54 9 11 61 77 2526 Fax : +54 11 4709 81 22 Pablo.ristori@gmail.com
Prof Pak Wai CHAN	Hong Kong Observatory (HKO) 134A Nathan Road Kowloon Hong Kong, China Tel: 85229268435 Fax: 85223752645 pwchan@hko.gov.hk
Dr Tetsu SAKAI	Meteorological Research Institute (MRI), Japan Meteorological Agency (JMA) 1-1 Nagamine Tsukuba-city, Ibaraki 305-0052 Japan Tel: +81-29-853-8583 Fax: +81-29-856-0644 tetsu@mri-jma.go.jp
Dr Siebren de HAAN ***Webex***	Royal Netherlands Meterological Institute (KNMI) Postbus 201 3730 AE De Bilt Netherlands Tel.: +31 30 2206 745 Fax: +31 30 2210 407 siebren.de.haan@knmi.nl
Dr Frank Beyrich ***Representative of Lindenberg (Germany) Testbed*** ***Webex***	Deutscher Wetterdienst (DWD) Meteorologisches Observatorium Lindenberg – Richard-Aßmann-Observatorium Am Observatorium 12 D-15848 Tauche / OT Lindenberg Germany Tel: +49 69 8062 5780 Fax:+49 69 8062 5710 frank.beyrich@dwd.de

Dr Alexander Hafaele ***for*** **Dr Dominique Ruffieux** ***Representative of Payerne (Switzerland) Testbed*** ***Webex***	MeteoSwiss Ch. de l'Observatoire 1530 Payerne Switzerland Tel: +41 26 662 6247 Fax: +41 26 662 6212 dominique.ruffieux@meteoswiss.ch
Dr Volker Lehmann ***Webex***	Deutscher Wetterdienst Meteorologisches Observatorium Lindenberg – Richard-Aßmann-Observatorium Am Observatorium 12 15848 Tauche OT Lindenberg Germany Tel: +49-69-80625740 Fax: +49-69-80625710 volker.lehmann@dwd.de
Dr Ruud Dirksen ***Webex***	Deutscher Wetterdienst Meteorologisches Observatorium Lindenberg – Richard-Aßmann-Observatorium Am Observatorium 12 15848 Tauche OT Lindenberg Germany Tel: Fax: Ruud.Dirksen@dwd.de
Dr Emilio Cuevas ***Representative of Izaña (Spain) Testbed***	C/La Marina 20 Planta 6 38071 Santa Cruz de Tenerife Spain Tel: +34 922 15 17 18 Fax: +34 922 57 44 75 ecuevas@aemet.es
Dr Gaelle CLAIN ***Representative of HMEI*** **Webex**	METEOMODEM Rue de Bessonville 77760 Ury, France Tel: +33 01 60 74 74 66 Fax: +33 01 60 74 74 19 gclain@meteomodem.com

WMO SECRETARIAT www.wmo.int/pages/prog/www/index_en.html	World Meteorological Organization 7, bis avenue de la Paix Case Postale 2300 CH-1211 GENEVA 2 **Switzerland**
Observing and Information Systems Department (OBS)	
Isabelle RÜEDI Senior Scientific Officer, Instruments and Methods of Observation (IMO)	Tel: +(41 22) 730 8278 Fax: +(41 22) 730 8021 E-mail IRuedi@wmo.int
Roger ATKINSON Scientific Officer, Instruments and Methods of Observation (IMO)	Tel: +(41 22) 730 8011 Fax: +(41 22) 730 8021 E-mail RAtkinson@wmo.int

Workplan of the Expert Team on New Remote-Sensing Technologies (2014-2018)
CIMO-16 §5.14, 5.15, 5.16 refer.
(Version: As approved by CIMO-MG-13 in Dec. 2014; updated in March 2016 and August 2016)

No.	Task description	Person responsible	Action	Deliverable	Deadline for deliv.	Status [%]	Comments
1.	**Instrument intercomparison for aerosol / volcanic ash detection.**	**Apituley** Donovan Ristori Sakai Haefele Cuevas (Ina Mattis)	1. Assist in conducting a feasibility study for an intercomparison on various techniques for aerosol/ volcanic ash detection 2. Report to CIMO MG on the findings of the study 3. Prepare a plan for such an intercomparison if feasible	1. Produce background document on lidar intercomparison 2. Draft report on feasibility study. 3. Plan for intercomparison	11/2016 04/2017 TBD	70 0 0	CIMO-16 § 5.24 In liaison with ET Inter- Comparison Will there be a need for 'portability' of the intercomparison?
2.	**Passive microwave profilers**	**Chan** Tully Payerne Testbed	1. Survey the use of MWPs by NMHSs 2. Further develop draft IOM report on operational use of passive microwave profilers. 3. Investigate potential integration with satellite data. 4. Review relevant CIMO Guide chapter and develop update.	1. Survey on MWP 2. IOM Report on MW Profilers 3. Advice on integration with sat data. 4. Updated CIMO Guide Chapter	12/2015 03/2018 12/2017 12/2017	100% 60% 0% 60%	CIMO-16 Doc. 5, §5.18 Note existing draft doc available from WMO secretariat Liaise with GRUAN.
3.	**Lidar Standards**	**Apituley** Chan	1. Provide WMO input to ISO TC146/SC5	1. WMO/ISO standard on Doppler wind	1. 02/2017	95% (under review)	CIMO-16, §4.6 CIMO-16, §5.22 CIMO-16, §8.3

No.	Task description	Person responsible	Action	Deliverable	Deadline for deliv.	Status [%]	Comments
			development of a joint WMO/ISO standard on pulsed heterodyne Doppler wind lidar. 2. Provide advice to CIMO MG on the merit of development of other joint WMO/ISO standards (e.g. CW Wind lidar). 3. Collaborate with ISO TC146/SC5 working group on maintenance of ISO lidar standards.	lidar	2. Ongoing 3. Ongoing		Re PHD wind lidar standard: Revision required by DWD after 'final version' circulated 05/16. After revision (10/16), standard to be circulated to WMO Members for formal WMO approval (3 months). WMO to comment to ISO on need for part 3 (CW lidar) by 30 Aug 2016
4.	**Monitor, evaluate and report on development and implementation of new remote-sensing technologies and their operational application (excluding weather radars, radar wind profilers and lightning detection systems)**	a. **Chan** Hafaele Tully b. **de Haan** Tulley	Review, evaluate and report on development and implementation of various new remote-sensing technologies and their potential/readiness for operational application, including path to operational use and traceability to SI, for: a. MWP b. GNSS	1. Updated reports on performance, implementation and operational use of various systems. 2. IOM or other report(s) on new RS technologies (e.g. Operational use of LIDARs in Argentina) 3. Relevant CIMO Guide updates (as required)	1. ongoing (update only if necessary) 2. 12/2016 (Argentinian lidar network IOM) 3. As req	ongoing 70%	CIMO-16 §4.17, 5.15, 5.16, 5.17, 5.18, 5.19, 5.20, 5.21, 5.22, 7(5).3, 7(5).4 Note 1: Ensure due consideration of new technologies which are cheap and simple to operate and maintain. Note 2: Take into account reports from previous intersessional period. Note 3: Liaise with GRUAN on WV Lidars, etc. Note 4: Include FTIR

No.	Task description	Person responsible	Action	Deliverable	Deadline for deliv.	Status [%]	Comments
		c. **Apituley** Ristori Sakai d. **Sakai** Apituley Roininen e. **Apituley** De Haan Chan f. **Donovan** g. **Ristori** Apituley Tulley Roininen Donovan. h. **???** i. **Apituley** All	c. Raman WV lidar d. DIAL lidar e. Doppler wind LIDAR f. cloud radars g. aerosol&volcanic ash detection h. FTIR i. other (incl. simple, cheap technology)				
5.	**Review outputs of assigned CIMO Testbeds (Lindenberg, Hohenpeissenberg, Payerne, Izana, Cabauw)**	**P.W. Chan** (Berger/Beyrich, Plass-Duelmer, Ruffieux, Cuevas, Bosveld)	1. Monitor and review outputs of assigned CIMO Testbeds and Lead Centres 2. Assess need to, and develop if required, relevant guidance material,	1. Report to OPAG Chair summarizing main outputs of Testbeds relevant to ET Terms of Reference 2. Revised CIMO Guide Chapters	1. 6 monthly report on relevant TB activities to ET Chair for inclusion in his report to OPAG Chair. 2. TBD	40%	CIMO-16, §5.15

No.	Task description	Person responsible	Action	Deliverable	Deadline for deliv.	Status [%]	Comments
			such as up-dates for CIMO Guide.				
6.	**Uncertainty and traceability to SI of remotely sensed atmospheric vertical profiles.**	**De Haan** All	1. Identify one technology (GNSS) for which SI traceability and quantification of uncertainty is tractable, and develop guidance material on this. 2. Identify a second technology and perform a similar analysis.	1. Document or IOM Report on uncertainty and traceability of GNSS measurements. 2. Report on another R/S profiling technique	06/17 12/17	50% 0%	Note existing draft document at http://www.wmo.int/pages/prog/www/IMOP/meetings/RS-NT/ET-NTTB-1/Doc%209_Traceability.doc CIMO-16 §5.25, 5.26 Liaise with similar GRUAN activities.
7	**Competencies for those involved in Aerosol lidar observations.**	**Ristori** Haefele	1. Develop a competency framework for all aspects of aerosol lidar observations.	1. Competency framework for aerosol lidar observations.	06/17	20%	Liaise with TT-Competencies
8	**Integrated water vapour profiling**	**Haefele**	1. Literature search on previous efforts 2. Draft an overview document	2. Technical report	12/17	0%	Include some or all of: MWP, ceilometers, cloud radar, WV lidar, sondes, NWP assimilated fields, GNSS, FTIR, mobile phones?!?

____