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COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATION

JOINT

**CIMO EXPERT TEAM ON
UPPER-AIR SYSTEMS INTERCOMPARISONS (ET on UASI)**
First Session

AND
**INTERNATIONAL ORGANIZING COMMITTEE (IOC) ON
UPPER-AIR SYSTEMS INTERCOMPARISONS**
First Session

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FINAL REPORT



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EXECUTIVE SUMMARY

This report provides a summary of the first session of the Joint Expert Team on Upper-Air Systems Intercomparisons (ET on UASI) and International Organizing Committee on Upper Air Systems Intercomparisons (IOC on UASI).

The ET/IOC discussed the Radiosonde Compatibility Report and suggested that the best way to use the results from the WMO Radiosonde Intercomparison was in coordination with the type of monitoring results reviewed in this report. Radiosonde stations where other equipment problems caused additional errors were readily identified from the Report.

The progress in the development of high quality upper-air measurements of temperature and water vapour and national progress reports on testing quality radiosondes were presented by the ET/IOC members and HMEI representatives.

The ET/IOC agreed to conduct Intercomparisons of High Quality Radiosonde Systems in Vacoas, Mauritius from 7 to 27 February 2005. At least eight radiosonde systems (both 403 MHz and 1680 MHz) will participate in the intercomparisons. This will require a new approach to planning the intercomparisons compared to past practice. Participating radiosondes will be divided into two groups and launched successively on 2000 g balloons at four launch times, 10h, 13h, 19h and 22h local time. The ET/IOC established a core Project Team comprising the ET/IOC Chairman, Project manager, Radiosonde Comparison Expert and Data Manager, supported by the local support staff. Internationally used WRSKOMP software will be used for data acquisition, processing, analysis and archiving of intercomparison data. The ET/IOC also developed a new strategy for publication of results to address the concern of manufacturers with the length of time to achieve publication of results. The ET/IOC agreed also on conditions for participation, intercomparison rules and responsibility of host and participants. The following are the main objective of the intercomparisons in Mauritius:

- a) To improve the accuracy of daytime radiosonde measurements and the associated correction procedures to provide temperature and relative humidity accuracies currently possible with nighttime measurements.
- b) To test the accuracy and availability as well as the general performance of data obtained from the GPS wind measuring systems.
- c) To evaluate the performance and usefulness of geometric and geopotential height values obtained from GPS radiosondes.
- d) To evaluate the differences of temperature, relative humidity and pressure sensors of widely used radiosondes against newly developed high performance sensors; and to identify, as far as possible, the origins of differences.
- e) To recommend the best combination of radiosondes to be used for referencing for GCOS and for satellite data calibration.
- f) To assess the practices used in the preparation of radiosondes for launch.
- g) To assess the added value of, and to develop procedures for use of remote sensing equipment in radiosonde systems intercomparisons.

GENERAL SUMMARY

1. ORGANIZATION OF THE SESSION

1.1 Opening of the session

1.1.1 The first session of the Joint Meeting of the Expert Team on Upper-Air Systems Intercomparisons (ET-UASI) and International Organizing Committee on Upper-Air Systems Intercomparisons (IOC-UASI) was held in Geneva, Switzerland, 17-20 March 2004. Dr John Nash, vice-president of CIMO and Chairperson of the ET-UASI and IOC-UASI, opened the session. The list of participants is given in [Annex I](#).

1.1.2 Following the opening of the session, Prof. Hong YAN, Assistant Secretary-General, welcomed the participants to Geneva and congratulated Dr Nash on being elected vice-president of CIMO. In his statement to the ET-UASI and IOC-UASI, he pointed out the importance of their work and wished them a productive meeting and an enjoyable stay in Geneva.

1.1.3 Dr John Nash also welcomed participants and wished everyone a fruitful and productive meeting.

1.2 Adoption of the agenda

1.1.4 The ET adopted the [Agenda](#) for the meeting, which is reproduced at the beginning of this report.

1.3 Working arrangements for the session

1.1.5 The working hours and tentative timetable for the meeting were agreed upon.

2. REPORT OF THE CHAIRMAN

2.1 Dr Nash presented a report of ET's activities since the establishment of the ET. He noted that in the current intersessional period, CIMO has been tasked with performing five instrument comparisons, one of those being a major Radiosonde Comparison in the WMO Radiosonde Comparison series.

2.2 The meeting was informed that Mauritius has volunteered to host the WMO Intercomparison of Radiosonde Systems in February 2005. It has been proposed that the test in Mauritius should be designated for high quality radiosonde systems, i.e. radiosondes systems based on operational radiosondes with additional high quality sensors.

2.3 In his report, Dr Nash noted that in recent WMO comparisons most effort during the planning phase has been concentrated on performing the fieldwork. Subsequently, significant problems have been encountered in completing the data analysis and issuing the final reports. It was recommended that the expert team would need to provide guidance on methods and responsibility for data processing and time scales for submission of the necessary results.

2.4 It was then noted that manufacturers were concerned with the length of time to achieve publication of the results from recent WMO Radiosonde Comparisons. In the light of these considerations, WMO has taken actions to ensure that data processing in the next tests will be supported under contract.

2.5 The chairman noted that the proposed intercomparison in Mauritius would not satisfy the requirements of all CIMO Members for Upper-air system Intercomparisons. The expert team will

have to identify those upper air systems that will need testing in addition to the Mauritius intercomparison.

2.6 There is a considerable national development of new radiosonde systems in progress. The expert team needs to develop procedures on archiving test results and making these useful for radiosonde data users. The expert team should also consider how international collaboration could be used to speed up the development of radiosonde systems.

2.7 Dr Nash concentrated on the preparation of the working plan for the next period. He noted that the WMO Secretariat had been very supportive in proposing the structure of the work plan for the expert team. The expert team adopted working procedures using more flexible arrangements

2.8 The expert team must be realistic in identifying the tasks it can undertake with the resources currently available. The membership of the expert team can be expanded if additional expertise is required.

2.9 The participants agreed that It is also important that benefits are seen to be delivered to the Hydro-Meteorological Equipment Industry Association (HMEI), so that WMO liaison with the manufacturers can be seen to work to mutual benefit

3. REVIEW OF THE PREVIOUS INTERCOMPARISONS AND TESTS

3.1 Review of previous WMO intercomparisons

3.1.1 Dr. Nash presented reviews of the temperature measurements and relative humidity measurements from the previous WMO intercomparisons.

3.1.2 Performance of the link radiosondes for temperature, i.e. Vaisala RS80 and VIZ radiosondes using rod thermistors was summarized. Nighttime measurements using the Vaisala RS80 had been similar during tests, apart from measurements at pressures lower than 100 hPa where Vaisala software corrections had introduced significant errors at pressures of 20 hPa and lower from 1984 until 1993. In contrast, the rod thermistor temperatures were less consistent than the Vaisala temperatures because of errors introduced by infrared radiative heat exchange. The nature of these errors could be shown using 3-thermistor radiosonde measurements as a reference (Phase IV and the Potential Reference Radiosonde Test (PREFRS), 1992. At 10 hPa the errors were larger than the software errors in early Vaisala measurements. These were found to be positive at very low temperatures (-80° C) and up to -2 K at higher temperatures (-40° C). Almost all radiosondes in use in the early 1980's had infrared cooling errors of various types. It was only in the 1990's that a significant number of radiosondes with temperature sensors were coated to minimize infrared heat exchange. These coated sensors provide good agreement in temperatures at night to pressures as low as 10 hPa.

3.1.3 In the daytime, it is difficult to estimate the individual radiosonde temperature errors from the tests. The tests where two pairs of three-thermistor radiosondes were flown provide the best estimates. These tests show major differences in daytime Vaisala RS80 temperatures at pressures lower than 100 hPa. The accuracy of the Vaisala daytime temperature correction procedures depends on the surface albedo and the amount of backscattering of solar radiation from clouds. In tests, in relatively clear conditions with the balloons flying over the sea (low albedo) the corrections applied were often too large and negative errors result at low pressure. When thick upper cloud was present throughout most test flights, the software corrections were too small and positive temperature errors resulted. No corrections had been applied to the VIZ rod thermistor temperatures, so the daytime errors were always positive at low pressures. These problems with the variability in daytime errors were found with all radiosonde types. Reduction of the errors is desirable in next generation radiosonde sensors, and the test in Mauritius should assess methods of producing better quality daytime temperature measurements

3.1.4 Relative humidity measurements were assessed using the performance of Vaisala RS80 measurements in dry conditions as the reference for checking calibration errors. This was because in the early phases of the WMO Intercomparisons, this type of sensor was assessed as having the best measurement reproducibility. In the lower troposphere, the accuracy of Vaisala RS80 measurements at high relative humidity was estimated from the values reported in cloud. At low relative humidity the Vaisala measurements were estimated to have positive bias on the basis of comparisons with measurements by the Snow White chilled mirror hygrometer. When all measurements from different sensor types were compared it was found that none of the radiosonde sensor designs available before 2000 was able to consistently meet the user requirement of 5 per cent accuracy in relative humidity, even in the lower troposphere. With more recent humidity sensor designs tested in the WMO GPS Radiosonde Intercomparison in Brazil, progress towards meeting this user requirements were evident. The test in Mauritius should evaluate progress in relative humidity sensor design. It should be expected that some of the sensor problems affecting measurements in Brazil and the WMO Relative humidity sensors test in 1995 have been rectified.

3.2 Presentations on recent national tests / comparisons

3.2.1 Mr Bower presented a report on the testing on new Radiosonde Replacement System (RRS), including the Telemetry Receiver System (TRS), Signal Processing System (SPS), Radiosonde Workstation (RWS), and the Radiosonde Surface Observing Instrument System, developed by the United States National Weather Service. The testing included following four major test and evaluation areas: functional repeatability, functional precision, functional reference comparison and functional comparison. The ET-UASI was informed that the development of the NWS RRS would include different sensor suites from those in current operational use. It was recommended that in order to assess the bias caused by the transition to different sensors approximately 200 dual radiosonde flight comparisons be performed at each of 13 to 19 sites in the NWS Upper Air network. This activity is anticipated to begin in 2006.

3.2.2 Dr Ivanov informed the meeting on the recent comparisons and testing quality of radiosondes, including requirements for further tests developed by the Russian Central Aerological Observatory (CAO). It was mentioned that CAO developed the PC-based data processing system. The Russian Federation actively participated in special comparisons, organized by different manufacturers and projects. It was noted that additional software for the express data evaluation has to be developed by WRSKOMP and CIMO community. The Russian Federation is ready to make an appropriate contribution to the mentioned development.

3.2.3 The meeting noted with interest the report, made by Dr Ishihara on the status of recent tests and comparisons of radiosondes operated by Japan Meteorological Agency (JMA). The meeting noted that JMA organized and took part in the WMO International Radiosonde Comparison Phase IV in Japan Aerological Observatory in 1999. In his report, Dr Ishihara submitted some results on: temperature compensation of the RH sensor of Meisei RS2-91, received during this comparison; comparison of Vaisala RS80-15GA with Meisei RS2-91; wind measurement missing for RS80-15GA and comparison of Vaisala RS92-AGP with Meisei RS2-91.

3.2.4 A report submitted by Dr Gaumet was based on the results of recent tests and comparisons of new RS 92 AGP sondes conducted by Météo France. The presentation included main characteristics of RS92-KL, RS92-AGP and M2K2 sondes, technical control of sondes, comparison results of ground and flight-testing of pressure, temperature and humidity sensors of these sondes. The participants were also informed on recommendations and conclusions for further tests and/or national intercomparisons.

3.2.5 Mr Klein Baltink presented a brief report on the recent test of RS90-AL and Snow White / RS80 radiosondes operated by the Royal Netherlands Meteorological Institute. The meeting noted with interest that one Snow White flight per month was scheduled in 2004 and 2005 to be synchronized with the overpass of SCIAMACHY on the board of ESA's ENVISAT satellite at the

location Paramaribo (5° 49' N 55° 9' W). It is also planned to have some additional launches in the framework of the EU project STAR. A comparison of Integrated Water Vapour from the RS90 radiosonde, GPS and 22-channel microwave radiometer showed in general good agreement but some bias was found. A comparison of the RS90 radiosonde humidity readings with data from the ARAS Raman Lidar operated during BBC2 is planned as soon as the data of the ARAS system have been processed. The Integrated Profiling Technique, recently developed by the University of Bonn, has been applied to the BBC2.

3.2.6 The meeting noted with interest the status report submitted by Dr Nash on the results of radiosonde testing and improvements to the Camborne test facility, operated by UK Met Office during 2002-2003. In the light of the report it was emphasized that tests were developed for military radiotheodolite evaluation (2001), RS90 humidity (February 2002), RS92 high power (October 2002), RS92 low power (May 2003), Meteorolabor Argus 37 (July 2003) and RS92 pre-acceptance test (December 2003). In accordance with Met Office future plans and requirements, Dr Nash informed the meeting that a large-scale acceptance test for the Vaisala RS92 radiosonde is planned in May/June 2004, but Snow White chilled mirrors and Sippican three-thermistor temperature sensing system will also be deployed to allow a better estimate of measurement accuracy. It is hoped that a collocated microwave radiometer, GPS water vapour and a cloud radar plus laser ceilometer will be used to judge the accuracy of the relative humidity measurements.

3.3 Progress of testing “universal” upper-air systems

3.3.1 The chairman noted that before automation of radiosonde observations became common it was usual for many radiotheodolite systems to be flexible in the type of radiosonde used with the ground system. The higher accuracy required with modern radiosondes systems has led to dedicated software developed by the manufacturer for specific radiosonde types. In several national networks where more than one radiosonde type has been used with a given ground system, the resultant processing has not been very consistent with the best practice associated with each radiosonde type.

3.3.2 The best radiosonde systems usually have resulted from test and development between the manufacturer and a number of national meteorological services with the capability to test radiosonde performance. Historically, many of the systems supplied by donors to the tropical upper air network have not been subject to this level of scrutiny before installation.

3.3.3 Mr Richard Thigpen informed the expert team that the newly activated GUAN station at Dar Es Salaam is to be equipped with a modern radiotheodolite system which also has capability to produce GPS wind measurements if required. This system is intended to be flexible in the radiosonde types that can be used.

3.3.4 The meeting was informed that the UK Met Office was to plan an operational demonstration of this system in Dar Es Salaam. Evaluation of measurement error characteristics would be performed in parallel with operations. Operational procedures for the equipment would be refined as testing progressed. The contract for the work will also include a test report prepared for the WWW department and the GCOS secretariat.

3.3.5 India has completed installation of 10 upper-air IMS 1500 systems that have capability to acquire and process data from several radiosonde types. The Indian radiosondes IMD MK-IV are used with the system at present, however it is planned to use also Sippican Mark IIA. The test of those systems still goes on and the feedback will be provided to the ET on UGRN and to the ET on UASI. India has the programme for upgrading more stations to this new “flexible” system.

3.4 National progress reports on testing quality of new radiosondes

3.4.1 Mr Hannu Jauhainen presented recent test results of Vaisala RS92 radiosonde. Comprehensive tests have been performed in ten countries in Europe, South-America and Asia.

RS92 radiosonde 12-channel code-correlated GPS wind measurement technology has proven to give major improvement in wind data availability, when compared to the codeless GPS-technology. In the test period August - December 2003 the average raw GPS wind calculation success rate was better than 99.9 % for 227 test soundings. Results of PTU-reproducibility sounding test were presented. For each pair the direct differences were calculated at all pressure levels. For the whole series the mean differences and standard deviation were calculated. The maximum difference for the temperature measurement was 0.05 °C, with standard deviation of 0.2 °C at 100 hPa and 0.4 °C at 10 hPa. Corresponding results for the humidity measurement were 0.4 % RH with standard deviation 1.6 % and for the pressure measurement 0.05 hPa with standard deviation 0.25 hPa.

3.4.2 Mr. Bower of the United States National Weather Service reported on testing quality of new radiosondes under the NWS Radiosonde Replacement System program. This is a first-of-a-kind 1680 MHz GPS, crystal controlled four-channel, circular polarized radiosonde. Results from tests of the Mark IIA and IMS 3010 radiosondes were presented. Corrected temperature data results using radiation correction algorithms including the use of information from the WMO Cloud Code Group for cloud cover, cloud type, and cloud base were presented. Issues with the new fast response, high-resolution sensors and the impact on WMO coded messages were discussed.

3.4.3 Mr Sai Krishnan presented the information on the status of current and future national upper-air activities developed by the India Meteorological Department (IMD), including testing quality of new radiosondes. The meeting noted modernization of the Indian network of upper-air radiosonde stations, including replacement of the obsolete radiotheodolites with the modern equipment and upgrading existing station with auto computation system using the new IMD-MKIV radiosondes, manufactured at the IMD facility in New Delhi. The IMD is upgrading radiosondes to a compact, lightweight, highly stable, repeatable, accurate radiosonde using the latest silicon pressure sensor. The whole system will be based on Application Specific Integration Circuit (ASIC).

3.4.4 Mr Guo Yatian presented results of the preliminary quality analysis for Chinese L-band radar-GTS1 Radiosonde upper-air observation system from China Meteorological Administration (CMA). In his report, Mr Guo Yatian, reported that the CMA began to develop the next generation of upper-air system, using new radiosondes with electronic sensors to measure meteorological elements. The radiosonde GTS1 works with L-band radar and it has rather strong anti-interference capability and very good measurement accuracy. Before putting GTS1 radiosonde into operational observation it was compared with GZZ2 and Vaisala RS80 radiosondes and the results of comparison were presented to the meeting. The preliminary statistics indicates that the GTS1 provides stable and reliable data for upper-air observation and it will be beneficial to numerical weather forecast.

3.5 Review of requirements for further tests / intercomparisons

3.5.1 The expert team reviewed the national reports in section 3.2. It became clear that at least seven manufacturers desired to attend the next WMO Radiosonde Intercomparison in Mauritius. This would require a new approach to planning the test, with radiosondes of a given type only flown under two conditions (day and night) during the test.

3.5.2 The expert recommended that some of the requirements for testing upper air systems would be best treated independently from the test planned in Mauritius, see section 7.2.3.

3.5.3 Given the significant costs of the test in Mauritius, the expert team noted that it would be unlikely that another large scale WMO Radiosonde Comparison be attempted within the present intersessional period.

3.5.4 The expert team agreed that efforts would need to be made to link developments of new radiosonde systems in China, India and Russia, and in the short-term this might be best performed by comparisons in these countries against radiosonde systems designated as high quality following

the Mauritius test. A suggested standard for high quality might be temperature accurate to 0.3 K (all heights), relative humidity accurate to 5 % (temperatures down to -60°C in the troposphere), and winds accurate to 0.5 ms⁻¹ (all heights). These needs will be discussed further by correspondence between the expert team members.

4. REPORT ON RADIOSONDE COMPATIBILITY

4.1 The chairman introduced extracts from the report of Mr J. Elms and Mr T. Oakley on radiosonde compatibility from 1998 until 2003.

4.2 He noted that of the 10 main radiosonde types now in use around the world, only two (Vaisala RS80 and Meisei RS2-91) are using sensors whose data can be reliably linked to the earlier WMO Radiosonde Comparison results.

4.3 For a given radiosonde station, the systematic bias averaged over 3 months between Vaisala RS80 radiosonde geopotential and first guess forecast at 100 hPa was usually within about ± 20 m of the average value for this radiosonde type. Twenty meters in 100 hPa geopotential corresponds to a range of ± 0.3 K in layer temperature from the surface to 100 hPa. The Meisei RS2-91 had similar consistency. Russian and Chinese radiosonde measurements mostly fell within a range of ± 35 m for the radiosonde type, corresponding to about ± 0.5 K range in layer temperature. The same evaluation for Indian radiosonde measurements shows a range of about ± 120 m between stations corresponding to about ± 2 K in layer temperature.

4.4 The report also showed that where the Vaisala RS80 was processed with a national ground system in the USA, the average bias was different from the rest of the world. This difference in performance from the rest of the world was more pronounced for the layer 30 to 100 hPa where the range in systematic bias in the North American network was about twice that found in the rest of the world. The origin of this difference has now been identified and was caused by a flaw in the radiation correction algorithm. The standard algorithm was supplied by the manufacturer, but it was not recognized by either party that a different data sampling rate in the US system would then lead to errors. This is an example where a careful flight comparison between the manufacturers standard equipment and that of the national variant should have uncovered the problem.

4.5 The general tendency for the systematic bias to increase with time in Asia, e.g. in Japan and in Hong Kong was noted. Further testing of Meisei and Vaisala radiosondes in the WMO Comparison Programme should help identify whether the monitoring fields have not been as stable as found in earlier monitoring periods.

4.6 The chairman noted that the best way to use the results from the WMO Radiosonde Comparison was in coordination with the type of monitoring results reviewed in this report. Radiosonde stations where other equipment problems caused additional errors were readily identified from the work of the Rapporteur.

5. PROGRESS IN THE DEVELOPMENT OF HIGH QUALITY UPPER-AIR MEASUREMENTS OF TEMPERATURE AND WATER VAPOUR

5.1 Dr Nash presented a summary of comparison results between the Vaisala RS90 and the Meteolabor chilled mirror hygrometer from the WMO GPS Radiosonde test in Brazil. Both the Snow white and the RS90 relative humidity measurements in Brazil were affected by technical problems that limited the measurement accuracy obtained. Significant numbers of RS90 measurements were contaminated in cloud at temperatures lower than -40° C. Snow white measurements became unstable at very low temperatures in most flights because of a change to the control electronics introduced by Meteolabor just before the experiment.

5.2 Detailed Comparison between Snow white and RS90 humidity measurements about 6 km above the ground showed that on occasions apparent noise in the Snow white was a correct

measurement, with the same fluctuations observed by the RS90, but smoothed out by the processing software.

5.3 In the lower troposphere, at temperatures higher than 0° C, the Snow white agreed closely with the RS90 on average, but in the day differences were much larger. Snow white reported relative humidity close to 100 per cent in daytime cloud, so there may have been notable errors in daytime RS90 relative humidity at high humidity.

5.4 Since the test in Brazil, both Snow white and the Vaisala RS90/92 sensors have been developed further. It is intended that the combination of the measurements from the two systems will be useful to evaluate other newer relative humidity sensors.

5.5 Mr. Hannu Jauhiainen presented the test results of RS92 radiosonde humidity measurements. In the new sonde, special attention has been paid to sensor stability, calibration accuracy after storage, and the elimination of the possible condensation of water vapor during sounding. Sensor stability at condensing environments was tested, giving 0.5% drift. Due to optimized sensor materials the humidity time constant test gave result 0.1 s at 25 °C temperature level and correspondingly 10 s at -40 °C temperature level. With the RS92 radiosonde, Vaisala has introduced a new reconditioning procedure to remove possible contaminants from the sensor surface and restore the original calibration accuracy. A defrosting method to eliminate sensor icing has been further developed. As a result of faster heating cycle the RS92 radiosonde detects the tops of low-level clouds more precisely than was previously possible. The effectiveness of an adaptive heating method was tested in Camborne by UK Met Office. Vaisala has improved the facilities for humidity sensor testing. Temperature dependence of the RS92 humidity sensor has been more accurately characterized.

5.6 Mr Remy Pepin introduced a new radiosonde GPSonde M2K2 from Modem. Sensors and sensor mounting had been improved to overcome limitations identified with the earlier design. Initial test results for this radiosonde were presented by Météo France, see paragraph 3.2.4.

5.7 The expert team members were shown samples of the use of the NASA ATM radiosonde as a high quality temperature measurement from test flights in the Potential Reference Radiosonde Test (PREFRS) hosted in the UK in 1992. The measurements are extremely useful in identifying the effect of cloud on temperature sensor accuracy. Accuracy achievable with the current design is about 0.2 K at low levels and 0.3 K at upper levels. The expert team agreed that the inclusion of the NASA-ATM in the Mauritius test would be of great benefit.

5.8 Both Snow white chilled mirror sensors and ATM sensors were considered to provide high quality measurements that would benefit the evaluation of the other sensors, so that costs of some of the sensors would be shared between the participants. Similarly, Vaisala proposed to the ET/IOC to fly the RS92 radiosonde on more of the flights than the other participants since this was considered of benefit to the experiment as a whole.

6. REVIEW OF RELEVANT GUIDANCE MATERIAL FOR NECESSARY UPDATES

6.1 Dr Gaumet presented an assessment of the Guidance material available for upper air operations. He noted that updated guidance material needs to take account the replacement of radiosondes with analogue transmitters with those using digital techniques. These new radiosondes offer more effective use of band width. Tests of the data links to these new types of radiosondes need to be performed so that guidance material at the ITU (submitted by WMO or HMEI) reflects the actual performance obtained. It is recommended that national tests be performed to check the radiofrequency properties of these new links.

6.2 Guidance material needs to reflect that the availability of Loran-C as a suitable navigation system for radiosonde windfinding is unlikely to continue in many parts of the world.

6.3 It is necessary to check whether the current documentation is adequate in describing the use of automatic launch systems, with minimal operator intervention. Also, the issues involved in attempting to develop modern radiosonde ground systems flexible enough to process the results from a variety of radiosonde from different manufacturers needs to be discussed.

6.4 The issues involved in the management of modern radiosonde software need to be addressed. For instance, should the manufacturers be expected to provide service level agreements to manage the conversion of radiosonde signals to meteorological variables. Should the national meteorological services be responsible for the transformation of meteorological variables into the variety of messages required by different users?

7. WMO INTERCOMPARISON OF HIGH QUALITY RADIOSONDE SYSTEMS WITH A PRIORITY GIVEN TO IMPROVED TEMPERATURE AND RELATIVE HUMIDITY MEASUREMENTS SINCE LAST WMO INTERCOMPARISON

In agreeing the procedures for the intercomparison, the ET/IOC followed the Procedures of WMO Global and Regional Intercomparisons of Instruments and Guidelines for Organizing WMO Intercomparisons of Instruments as specified in the *Guide to Meteorological Instruments and Methods of Observation, WMO-No.8, Chapter 5, Annex 5.A and 5.B* and Guidelines for organizing radiosonde intercomparisons and for the establishment of test sites as specified in ANNEX III. Items 7.1 to 7.4 describe only issues in addition to the above standard practices.

7.1 Main objectives, place, date and duration

7.1.1 The ET/IOC agreed on the following main objectives of the planned intercomparison:

- a) To improve the accuracy of daytime radiosonde measurements and the associated correction procedures to provide temperature and relative humidity accuracies currently possible with nighttime measurements.
- b) To test the accuracy and availability as well as the general performance of data obtained from the GPS wind measuring systems.
- c) To evaluate the performance and usefulness of geometric and geopotential height values obtained from GPS radiosondes.
- d) To evaluate the differences of temperature, relative humidity and pressure sensors of widely used radiosondes against newly developed high performance sensors; and to identify, as far as possible, the origins of differences.
- e) To recommend the best combination of radiosondes to be used for referencing for GCOS and for satellite data calibration.
- f) To assess the practices used in the preparation of radiosondes for launch.
- g) To assess the added value of, and to develop procedures for use of remote sensing equipment in radiosonde systems intercomparisons.
- h) To publish the Executive Summary within two months after the Intercomparison, which will be presented at TECO-2005. The draft Final Report will be ready by January 2006 and the approved Final Report shall be ready in March 2006 for publishing in the *WMO Instruments and Observing Methods Report (IOM)* series.

7.1.2 Following the invitation from the Permanent Representative of Mauritius with WMO and the detailed presentation of the facilities and infrastructure of the proposed intercomparison site as well as the commitment of the host country, the ET/IOC agreed to organize the intercomparison in Vacoas, Mauritius from 7 to 27 February 2005. Dr Beenay Pathack was nominated to be the Project Manager.

7.2 Procedures for intercomparisons (conditions for participation, type of instruments, identification of participants, intercomparison rules, responsibility of the host and responsibility of participants, radiofrequency issues, possibility of remote sensing systems as references)

Type of instruments and identification of participants

7.2.1 The ET/IOC selected the following radiosondes that will be accepted to participate in the intercomparison:

No.	Manufacturer	Radiosonde	Tracking / Navigation System	Possibility to attach additional sensors	Support staff during comparison
1	Vaisala Oyj	RS92	GPS 403 MHz	4 sensors	4
2	SIPPICAN Inc	MARK IIA	GPS 403 MHz	5 Thermistors Snow White	2
3	MODEM	M2K2	GPS 403 MHz	3 sensors	2
4	MEISEI Electric Co. Ltd.	RS-01G	GPS 403 MHz	3 sensors	2
5	GRAW Radiosondes GmbH	DFM97	GPS 403 MHz	3 Thermistors	2
6	Meteolabor AG	SRS C34	GPS 403 MHz	Snow White plus 5 thermometers	2
7	International Met Systems	IMS 4010	RDF1680 MHz GPS 1680 MHz	1 Thermistor	2
8	NASA	ATM	GPS 403 MHz	-	2

7.2.2 Participants will inform the chairman of ET/IOC and Project Manager, not later than November 2004, on their decision on which additional sensors will be used with the radiosondes. The Chairman of the ET/IOC will then inform participants on whether their proposal is accepted.

7.2.3 Participation of the new Chinese GTS1 1680 MHz radiosonde, the new Indian IMD – MKIV 1680 MHz radiosonde and the new Russian 1680 MHz radiosonde was also discussed. The ET/IOC agreed that further national tests would be needed before their participation in the major WMO Intercomparison. The ET may assist in those national tests if requested. Due to the logistics (all 1680 MHz radiotheodolites and secondary radar), the test should be done in or near the country of origin. The UK was requested to consider assisting in the test of all three radiosondes with the assistance from JMA, in testing the new Chinese radiosonde.

7.2.4 Representatives of the Russian Federation and India decided not to participate in the Mauritius Intercomparison. For the possible participation of Chinese GTS1 radiosonde in the intercomparison, the representative of China must inform the Chairman of the ET/IOC before 15 April 2004.

Intercomparison rules

7.2.5 Daily launches will be conducted at 10h, 13h, 19h and 22h local time. The radiosondes will be divided into two groups launched successively on 2000 g balloons based on the below arrangements.

Group 1		Group 2	
Radiosonde	Participation in individual flight	Radiosonde	Participation in individual flight
RS92	100 %	ATM	100 %
M2K2	100 %	MARK IIA	100 %
RS-01G	100 %	DFM97	100 %
SRS C34	100 %	IMS	100 %
ATM	Of about 50 %	RS92	Of about 40 %
		SRS C34	Of about 30 %

7.2.6 The ET/IOC Chair will prepare a detailed plan of individual radiosonde launches in October 2004.

7.2.7 Mr. Ruppert of Meteolabor offered to provide a Thygan hygrometer for ensuring that surface relative humidity measurements were of good quality. The expert team noted that this equipment had been very useful in Brazil and gratefully accepted the offer.

7.2.8 Dr. Pathack noted that there was a wind finding radar at the proposed test site. The usefulness of this radar in providing a vertical height reference would depend on the size of the range gates, given that winds would normally be light during the test period. The ET/IOC Chairman would discuss the usefulness of this system and whether some measurements from the usual operational radiosonde system used in Mauritius should be included on some of the intercomparison flights, including winds derived from the radar.

7.2.9 It was agreed that the length of the suspension from the balloon to the radiosondes should normally be 40 m, especially during the time when local staff were becoming used to launching comparison flights. It was agreed that some unwinders (heavy duty Graw) should be purchased to minimize gaps in the test programme if conditions became windy near the surface.

Responsibility of the host and responsibility of participants

7.2.10 Evidence is required by November 2004 from participants to demonstrate the stability of the sensors performance and designs of all participating radiosonde systems.

7.2.11 InterMet Systems will need to provide relevant data results related to the demonstration flights of their new radiosondes by December 2004. It will also provide evidence that its 1680 MHz radiosonde system will be compatible with those of 403 MHz.

7.2.12 Participants will provide detailed specification of their radiosonde systems to the ET/IOC Chairman and the Project Manager by June 2004.

7.2.13 The ET/IOC recognized the substantial work to be done on site and recommended that the host country appoints an assistant Project Manager.

7.2.14 Given the large number of participants involved in working at night, the Project Manager is requested to check that illumination will be sufficient for the external work areas.

7.2.15 The ET/IOC agreed that the following experts are required to support the host country and the Project Manager: the ET/IOC Chairman, Data Manager, and Radiosonde Comparison Expert. The ET/IOC agreed that Mr Sergey Kurnosenko would take over the responsibility of Data Manager and Mr Richard Smout the responsibility of Radiosonde Comparison Expert. The TORs of the above functions are in ANNEX IV.

7.2.16 The Chairman noted that in the previous test in Brazil, teams of four or five local staff had been used to prepare the balloons and manage the data reception facility. Two teams had been responsible for two flights each per day. This should give some idea of the size of the project team required. The ET/IOC Chairman would discuss details of requirements in more detail with the Project Manager.

7.2.17 The Project Manager is requested to inform participants as soon as possible about procedures for shipping equipment to Mauritius, including the minimum time necessary for equipment to be cleared through customs.

7.2.18 The expert team suggested that GPS time be used as a reference between the different ground systems. The participants are requested to consider whether accurate time sampling of data samples could be achieved by this method. If this is possible, then the data manager is requested to identify whether this is practical for the current data processing software. Otherwise, the Radiosonde Comparison Expert is requested to provide a method of data synchronization for the experiment.

Conditions for participation

7.2.19 The participating manufacturers will cover the overheads related to the organization of the intercomparison. Those are related to the participation of the Data Manager in the intercomparison, consumables needed for the intercomparison (balloons, gas, 40-m unwinders, strings) and 20 pieces of Snow White and ATM sensors each. These overheads will be shared equally among participating manufacturers.

7.2.20 SIPPICAN Inc. will purchase and make available for others the above-mentioned consumables. In the case of gas, the purchase will be organized on site by the Project Manager and reimbursed by HMEI representative.

7.2.21 US NWS will donate parachutes and Mauritius will arrange necessary amount of bamboo poles for making radiosonde flight rigs.

7.2.22 WMO representative informed the ET/IOC meeting that no financial support towards the participation of the manufacturers and their equipment/radiosondes in the WMO Intercomparison is possible. However, WMO will attempt to assist in the participation of the chairman of the ET/IOC and the radiosonde intercomparison expert in the WMO Intercomparison.

Radiofrequency issues

7.2.23 The Project Manager will make sure that 403 MHz and 1680 MHz frequencies may be used during the intercomparison and inform the ET/IOC Chair not later than June 2004.

7.2.24 The participants agreed to provide details of the radiofrequency characteristics of their systems to the ET/IOC Chairman not later than June 2004. The Radiosonde Comparison Expert would then propose specific frequencies to be used by the individual participants.

Possibility of remote sensing systems as references

7.2.25 The ET/IOC recognized that several (operational) remote sensing systems could be deployed to support the Intercomparison and the assessment of the quality of the data acquired with the radiosondes. Considering that three main parameters i.e. wind, temperature and relative humidity are of interest the options for actual use of remote sensing systems for these three is summarized. However it is noted that remote sensing systems will not deliver data with a significant better accuracy than the radiosonde to be operated during the intercomparison. Furthermore operation of remote sensing should be limited to systems that are easy to install and deploy and can run autonomous and with little or no supervision of experts.

7.2.25 Integrated Water Vapour. Two-channel microwave radiometer can measure Integrated Water Vapour (IWV) and Liquid Water Path (LWP), multi-channels radiometers could provide (by inversion techniques) coarse profiles of temperature and humidity at high temporal resolution. Mr Schmidlin agreed to contact research scientists from the University of Wisconsin to determine availability of their microwave water vapour instrument and whether it could be transported to Mauritius.

7.2.26 Clouds. Lidar ceilometers measure the cloud base and can be operated autonomously. However ceilometers cannot penetrate deep into optical thick (water) cloud and multiple cloud layers cannot be detected in these cases. High level ice clouds may also not be detected. Nevertheless the ET/IOC encourages the installation of one or more ceilometers. Mr Klein Baltink agreed to investigate the availability of a CT75 ceilometer. Micro Pulse Lidar (MPL) is more sensitive than ceilometer and could provide additional information on upper level clouds. The availability of such a system should be investigated. Cloud top can be best detected with a cloud radar. However, these systems are usually expensive, and relative few systems are in operation.

7.2.27 Temperature and relative humidity profiles. LIDAR (Raman, DIAL) are capable of measuring temperature in the (lower) troposphere if the signal is not blocked by clouds. This could provide valuable data for comparison with radiosondes. However these systems are expensive and need experts to run. Such a system is not likely to be available for the intercomparison.

7.2.28 Wind. Wind profilers can provide profiles of horizontal wind and estimates of the boundary layer height. Only mobile system can be considered here which are limited to measurements in the lower troposphere. Addition of a RASS to the profiler will also measure (virtual) temperature profiles up to a relative low height.

7.3 Data acquisition and data policy

7.3.1 The ET/IOC agreed that the WRSKOMP software, developed by Mr Kurnosenko, will be used for data acquisition and archiving of data in the WMO Radiosonde Intercomparison in Mauritius.

7.3.2 The participants will provide samples of their data output by August 2004 to the Data Manager who will then make conversion from individual data formats to an intercomparison format.

7.3.3 Data will be considered in all cases after radiation corrections are applied with the vendor algorithm. Data for each flight will be provided to the data manager within one hour after completion of sounding. Manufacturers may provide the raw data sets that will be stored by Project manager and ET/IOC Chairman for future reference in case of a need to resolve deficiencies. Manufacturers that do not provide the raw data sets will make their own arrangements for data storage.

7.3.4 The Time increment during the ascent will be limited to a resolution of 1 second. The standard quality controlled data output will have the following format:

Column	Data	Units	Resolution
1	Time	Seconds	1.0
2	Pressure	hPa	0.1

3	Temperature	Degrees C	0.1
4	Relative Humidity	%	1.0
5	Height	Meters	1.0
6	Direction	Degrees	1.0
7	Speed	m/s	0.1
8	(Reserved)		
9	Thermistor 2	Degrees C	0.1
10	Thermistor 3	Degrees C	0.1
11	Thermistor 4	Degrees C	0.1
12	Thermistor 5	Degrees C	0.1
13	Snow White RH	%	1.0
14	Peltier Cooler Current	mA	1.0
15	Battery Voltage	V	0.1
16	Snow White Internal Temperature	Degrees C	0.1
17	Mirror Temperature	Degrees C	0.1
18	Spare		
19	Spare		
20	Spare		

7.3.5 The uncorrected raw data will have the following format:

Column	Data	Units	Resolution
1	Time	Seconds	1.0
2	Pressure	hPa	0.1
3	Temperature	Degrees C	0.1
4	Relative Humidity	%	1.0

7.3.6 Each vendor has the right to their own data for each flight as well as data from corresponding reference measurements for their respective flight. The Chairman of the ET/IOC will produce a summary of data results for presentation during TECO-2005. Each vendor can publish results of their own work (own data) including corresponding temperature and relative humidity reference data after TECO-2005.

7.3.7 All edited data from each vendor as well as data from reference instruments will be provided to all vendors by the Chairman of the ET/IOC in October 2005 as part of the preparation for the ET/IOC Initial Data Results Review, November 2005.

7.3.8 Individual vendors may not publish comparative results until after the intercomparison final report.

7.4 Processing and analysis methodology and publication of results

7.4.1 Mr Kurnosenko presented in details the proposal for processing analysis and methodology based on WRSKOMP software, the version of which was already successfully used in number of WMO Intercomparisons, regional and national tests. It was also used by some National Meteorological Services and manufacturers during their testing exercises, such as UK Met Office, Météo Swiss, and Vaisala Oyj.

7.4.2 The ET/IOC agreed to use the WRSKOMP software for processing and analysis in the WMO Radiosonde Intercomparison in Mauritius.

8. WORK PLAN

8.1 The outcome of the discussion on the above agenda items were recast into a detailed Work Plan that specifies actions and deliverables for all tasks that were put forward to the team by CIMO-XIII and CIMO-MG. The Work Plan is in ANNEX II.

9. AOB

9.1 Training programme for RICs to perform intercomparison tests of new radiosonde systems for climate purposes

9.1.1 The Chairman presented a brief paper on the possibility of providing additional overlap tests when a new radiosonde type in worldwide use is introduced.

9.1.2 It was agreed that additional overlap tests would be useful, where the local conditions (cloudiness, temperature and relative humidity structure in the vertical, reflection of solar radiation from the surface) are quite different from the WMO and National Radiosonde test sites.

9.1.3 Whilst at least one country was planning to perform extensive overlap tests, for different seasons and different regions, there were large areas of the world where no testing was yet planned, e.g. Region I.

9.1.4 For an overlap test to be most useful it was necessary to perform the test in a manner that allowed the origin of the differences to be identified. For instance, were the differences measured resulting from changes in temperature and humidity sensor performance? Alternatively were changes in height/pressure assignment techniques causing problems? Were differences in software or sensor adjustment techniques applied by software the origin of changes? The expert team needs to prepare recommendations on the information and test procedures necessary to check these issues.

9.1.5 The chairman suggested that a proposal for overlap testing for the transition from Vaisala RS80 to Vaisala RS92 at a suitable RIC in Region I, be forwarded to the President of CIMO and the CIMO Management Committee for their consideration.

9.2 Cooperation with other Technical Commissions

9.2.1 The Commission for Climatology welcomed the opportunity for inter-commission discussions on issues related to the importance of Upper Air (UA) data and metadata, data accuracy and homogeneity and instrument inter-comparisons. In particular the CCI stressed the importance of UA data to global understanding of the Earth's climate system, and to research efforts to detail past and future Earth climates. It is vital to understand how much variation in the observed data is due to the climate and how much is due to varying instrumentation and observational procedures over time. NMHSs are under considerable pressure to reduce the numbers of upper air observing stations and to increase use of observations from aircraft, satellites and other platforms. Replacement of traditional radio sounding processes and instruments with new ones will have a negative impact on the homogeneity of the UA records, without proper planning of the introduction of the new technologies, and best practices such as regular instrument inter-comparisons and operational measurement overlap covering a full seasonal cycle and applied within various climate regimes.

9.2.2 The IPCC, in its Fourth Assessment report, noted factors related to uncertainty in assessment of UA Temperature data (for example), related to measurement errors, data discontinuities, and incomplete spatial and temporal sampling (ref. Section 2.2.3, pgs 119-123). Accurate, consistent UA climate data, adequately sampled in both space (3-D) and time and with common formats, resolution and reporting intervals, are vital to operational and research efforts. In order to ensure that such data are developed and available for climate analysis, prediction, reanalysis and for climate projection, the CCI recommends continued inter-commission collaboration on common issues, especially regarding quality, accuracy, consistency, comparability and availability of observational and intercomparison data and metadata. The CCL recognizes the need within the UA network community for decision-support guidance, and further recommends that its Members develop a clear Statement of Data Requirements for UA and other climate data.

10. DRAFT REPORT OF THE SESSION

10.1 The members of expert team prepared their inputs for the Final Report, a draft of which was subsequently prepared by the Secretariat. The meeting requested Secretariat to send the draft to participants for further evaluation and comments.

11. CLOSURE OF THE SESSION

11.1 The session was closed on 20 March 2004 at 15h30.

ANNEX I

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ANNEX II

WORK PLAN
Expert Team on Upper-Air Systems Intercomparisons
(2003-2006)

No.	Task description	Person responsible	Action	Deadline	Deliverables	Deadline
1	Improve the global radiosonde network:					
1 a)	In collaboration with HMEI, organize and evaluate WMO radiosonde intercomparisons to detect error characteristics of various types of aerological measurement systems and deal with the technical issues involved in modernizing and improving the accuracy of the radiosonde component of the upper-air network	John NASH	1. Finalize results of outstanding intercomparisons:		<ul style="list-style-type: none"> • IOM Reports on one CD 	Oct.04
Frank Schmidlin		a. GPS Radiosonde Comparison – Brazil	Aug.04			
		b. Radiosonde Relative Humidity Sensors Intercomparisons – Russia/USA 1995-1997	May.04			
		c. Summary of the first five WMO Radiosonde Comparisons	Sep.04			
	2. Analysis of benefits from including remote sensing systems	May.04	<ul style="list-style-type: none"> • Report on Benefits from inclusion of remote sensing systems 	Jun.04		
Henk KLEIN BALTINK	3. Planning for intercomparisons of candidate systems	Dec.04	<ul style="list-style-type: none"> • Publication of new proposed working “reference” for future radiosonde comparisons 	May.06		
John NASH			<ul style="list-style-type: none"> • Updated guidance on radiosonde error characteristics 	Feb.06		

No.	Task description	Person responsible	Action	Deadline	Deliverables	Deadline
1 b)	Coordinate testing of new radiosonde types in conjunction with HMEI	Yatian GUO Carl BOWER	1. Review the existing procedures and develop recommendation for intercomparisons/testing of new radiosonde types 2. Monitor testing on Regional and National levels	Mar.05 Jun.05	<ul style="list-style-type: none"> • Report for TECO on Recommendation for testing of new types of radiosondes • Annual reports on radiosonde testing 	Mar.04 End of calendar year.
1 c)	Review procedures of publication of results of WMO Radiosonde Comparisons	Jean-Louis GAUMET Carl BOWER	1. Develop procedures of publication of results of WMO Radiosonde Comparisons	Jan.05	<ul style="list-style-type: none"> • Report on Reference procedures for radiosonde intercomparisons • Proposal for update of CIMO Guide 	Feb.05 Dec.05
1d)	Review policy for data processing in WMO Intercomparisons	Frank Schmidlin	1. Develop policy for data processing in future WMO Intercomparisons and tests	Sep.04	<ul style="list-style-type: none"> • Report on agreed policy for data processing in future WMO Intercomparisons and tests 	Dec.04
1 d)	Organize and evaluate WMO intercomparisons of remote and in situ U/A sounding systems	John NASH & Beenay PATHACK & Sergey Kurnosenko	1. Identify possible host countries for the intercomparisons 2. Define and agree on the organization of the intercomparisons, namely: main objective, place, date, duration, conditions for participation, data acquisition, processing and analysis methodology, publication of results, intercomparison rules,	Mar.04 Mar.04	<ul style="list-style-type: none"> • Published results of the intercomparisons 	Dec.05

No.	Task description	Person responsible	Action	Deadline	Deliverables	Deadline
			responsibility of the host(s) and responsibilities of participants 3. Identify type of instruments and participants for the intercomparisons 4. Overall supervision and coordination of the field intercomparisons	May.04 Feb.05		
2	Provide advice on <i>Quality Management Systems</i> procedures for instruments and methods of observation (based on the CIMO Guide) and implement links with relevant international organization active on this area					
2 a)	Develop performance measures to demonstrate continuous improvement in the quality of upper-air observations	Bertrand Calpini Carl BOWER	1. Elaborate global criteria for tracing the improvements of radiosondes based on: <ul style="list-style-type: none"> • Previous intercomparisons, • Recent radiosonde development; and including remote sensing 	Oct.05	<ul style="list-style-type: none"> • IOM Report on Global criteria for tracing the improvements of radiosondes 	Dec.05
2 b)	Contribute to the review and update of WMO Technical Regulations, Guides and other material related to Quality Management and standardization of observations	Henk KLEIN BALTINK & all ET members	1. Prepare proposal for relevant updates of CIMO Guide on the basis of recent national and international radiosonde comparisons and on the review of the recent scientific literature	Oct.05	<ul style="list-style-type: none"> • CIMO Guide updated • Proposals submitted to CIMO-XIV 	Nov.05 Feb.06

ANNEX III

GUIDELINES FOR ORGANIZING RADIOSONDE INTERCOMPARISONS

(CIMO-XII, Casablanca, Morocco, May 1998
Abridged Final Report, WMO-No. 881
Annex to paragraph 5.1.8 of the general summary)

PART I - GUIDELINES FOR ORGANIZING RADIOSONDE INTERCOMPARISONS

1. Introduction

1.1 These guidelines assume that procedures that may be established by various test facilities are consistent with procedures established by other national and international organizations. They also assume that an Organizing Committee (OC) will be formed of participants (Members) interested in comparing radiosondes and that at least one non-participant will be included with ability to provide guidance for conducting the intercomparison. The involvement of an independent non-participant is important in order to avoid bias during the planning of the intercomparison. Consideration must also be given to whether radiosonde manufacturers' personnel should actively participate or whether independent operational personnel of the host should prepare and fly such radiosondes.

1.2 All intercomparisons differ from each other to some extent, therefore, these guidelines are to be construed only as a generalized checklist of tasks needing to be accomplished. Modifications should be made by the OC, as required, but the validity of the results and scientific evaluation should not be compromised.

1.3 Final reports of previous intercomparisons and organizational meeting reports of other OCs may serve as an example of the methods that can be adopted for the intercomparison. These previous reports should be maintained and made available by the Secretariat.

2. Objectives of intercomparisons

2.1 The intercomparison objectives must be clear, must list what is expected from the intercomparisons and identify how results will be disseminated. The OC is tasked to examine the achievements to be expected from the radiosonde intercomparison and to identify and anticipate any potential problem. The OC's role is to provide guidance, but it must also prepare clear and detailed statements of the main objectives and agree on the criteria to be used in evaluating the results. The OC should also determine how best to guarantee the success of the intercomparison by drawing on background knowledge and accumulated experience from previous intercomparisons.

3. Place, date and duration of intercomparison

3.1 The host facility should provide to the OC and to the participants a description of the proposed intercomparison site and facilities (locations, etc.), environmental and climatological conditions, and site topography. The host facility should also name a Project Leader (PL) or Project Manager who will be responsible for the day-to-day operation and act as the facility point of contact.

3.2 The OC should visit the proposed site to determine the suitability of its facilities and to propose changes, as necessary. After the OC agrees that the site and facilities are adequate, a site and environmental description should be prepared by the PL for distribution to the participants.

The PL, who is familiar with his facility's schedule, must decide the date for the start of the intercomparison, as well as its duration. A copy of this schedule shall be delivered to the OC.

3.3 In addition to the starting date of the intercomparisons, the PL should propose a date when his facility will be available for the installation of the participant's equipment and arrange for connections to the data acquisition system. Time should be allowed for all of the participants to check and test equipment prior to starting the intercomparison and to allow additional time to familiarize the operators with the procedures of the host facility.

4. Participation

4.1 As required, the PL and/or OC should invite, through the Secretary-General of WMO, participation of Members. However, once participants are identified, the PL should handle all further contacts.

4.2 The PL should draft a detailed questionnaire to be sent by the Secretary-General to each participant in order to obtain information on each instrument type proposed to be intercompared. Participants are expected to provide information on their space, communication, unique hardware hookup requirements, and software characteristics. They also should provide adequate documentation describing their ground and balloon-borne instrumentation.

4.3 It is important that participants provide information about their radiosonde calibration procedures against recognized standards. Although it is expected that operational radiosondes will be intercompared, this may not always be the case; new or research-type radiosondes may be considered for participation with the agreement of all of the participants, the PL, and the OC.

5. Responsibilities

5.1 Participants

5.1.1 The participants shall be responsible for the transportation of their own equipment and costs associated with this transportation.

5.1.2 The participants should install and remove their own equipment with the cognizance of the PL. The host facility shall assist with unpacking and packing, as appropriate.

5.1.3 The participants shall provide all necessary accessories, mounting hardware for ground equipment, signal and power cables, spare parts and expendables unique to their system. The participants shall have available (in the event assistance from the host facility becomes necessary) detailed instructions and manuals needed for equipment installation, operation, maintenance and, if applicable, calibration.

5.2 Host facility

5.2.1 The host facility should assist participants in the unpacking and installation of equipment as necessary, and provide storage capability to house expendables, spare parts, manuals, etc.

5.2.2 The host facility should provide auxiliary equipment as necessary, if available.

5.2.3 The host facility should assist the participants with connections to the host facility's data acquisition equipment, as necessary.

5.2.4 The host shall insure that all legal obligations relating to upper-air measurements (e.g., the host country's aviation regulations, frequency utilization, etc.) are properly met.

5.2.5 The host facility may provide information on accommodations, local transportation, daily logistics support, etc., but is not obligated to subsidize costs associated with personnel accommodations.

6. Rules during the intercomparison

6.1 The PL shall exercise control of all tests. He will keep a record of each balloon launch, together with all the relevant information on the radiosondes used in the flight and the weather conditions.

6.2 Changes in equipment or software will be permitted with the cognizance and concurrence of the PL. Notification to the other participants is necessary. The PL shall maintain a log containing a record of all the equipment participating in the comparison and any changes that occur.

6.3 Minor repairs (e.g., fuse replacement, etc.) not affecting instrumentation performance are allowed. The PL should be made aware of these minor repairs and also submit the information to the record log.

6.4 Calibration checks and equipment servicing by participants requiring a specialist or specific equipment will be permitted after notification to the PL.

6.5 Any problem that compromises the intercomparison results or the performance of any equipment shall be addressed by the PL.

7. Data acquisition

7.1 The OC should agree on appropriate data acquisition procedures such as measurement frequency, sampling intervals, data averaging, data reduction (this may be limited to individual participant's capability), data formats, real-time quality control, post-analysis quality control, data reports, etc.

7.2 All data acquisition hardware and software provided by the host facility should be well tested before commencement of the intercomparison.

7.3 The time delay between observation and delivery of data to the PL shall be established by the PL and agreed on by the participants. One hour after the end of the observation (balloon burst) should be considered to be adequate.

7.4 The responsibility for checking data prior to analysis, the quality control steps to follow, and delivery of the final data rests with the PL.

7.5 Data storage media shall be the PL's decision after taking into consideration the capability of the host facility, but the media used to return final test data to participants may vary in accordance with each of the participant's computer ability. The PL should be cognizant of these requirements.

7.6 The PL has responsibility for providing final data to all participants and, therefore, the host facility must be able to receive all individual data files from each participant.

8. Data processing and analysis

8.1 Data analysis

8.1.1 A framework for data analysis should be encouraged and decided upon even prior to beginning the actual intercomparison. This framework should be included as part of the experimental plan.

8.1.2 There must be agreement among the participants as to methods of data conversion, calibration and correction algorithms, terms and abbreviations, constants, and a comprehensive description of proposed statistical analysis methods.

8.1.3 The OC should verify the appropriateness of the analysis procedures selected.

8.1.4 The results of the intercomparisons should be reviewed by the OC, who should consider the contents and recommendations given in the final report.

8.2 *Data processing and database availability*

8.2.1 All essential meteorological and environmental data shall be stored in a database for further use and analysis by the participants. The PL shall exercise control of these data.

8.2.2 After completion of the intercomparison, the PL shall provide a complete set of all of the participants' data to each participant.

9. **Final report of the intercomparison**

9.1 The PL shall prepare the draft final report which shall be submitted to the OC and to the participating members for their comments and amendments. A time limit for reply should be specified.

9.2 Comments and amendments should be returned to the PL with copies also going to the OC.

9.3 When the amended draft final report is ready, it should be submitted to the OC, who may wish to meet for discussions, if necessary, or who may agree to the final document.

9.4 After the OC approves the final document for publication, it should then be sent to the Secretariat for publication and distribution by WMO.

10. **Final comments**

10.1 The OC may agree that intermediate results may be presented only by the PL, and that participants may present limited data at technical conferences, except that their own test data may be used without limitation. Once the WMO Secretariat has scheduled the final report for publication, the WMO shall make the data available to all Members who request them. The Members are then free to analyse the data and present the results at meetings and in publications.

ANNEX IV

Terms of Reference of Data Manager

The Data Manager will be responsible for incorporating all the information supplied by the participating systems into the Intercomparison data base. He will check that all data are entered correctly. At the end of the comparison he will provide the completed data set plus the software to complete the necessary data analysis for the comparison. He will also support the project team in exploiting all the facilities made available with the software,

- A. Before the intercomparison the data manager will contact the participants to ensure that suitable input software exists for all the necessary data, both raw and processed.
- B. During the intercomparison, the Data Manager will:
1. Guarantee the necessary QA/QC procedures during the intercomparisons.
 2. Ensure that test data are input to the data set within 1 hour of the end of the test flight.
 3. Ensure that the participants check that the data recorded in the data set are consistent with the original data provided to the Data Manager.
 4. Ensure that the accuracy of conversion of measurements to the data base units (e.g. from knots to ms^{-1} for winds) will be validated with the relevant participant.
 5. Prepare suitable outputs for data review meetings of the Project Team.
 6. Take actions to rectify malfunction of the provided software.
 7. Guarantee the permanent management of the intercomparison data base, including safe back-up.
 8. He will train the Project staff in Mauritius in the use of the software package, to the extent required by the Project Leader.
- C. At the end of the intercomparison, the Data Manager will provide the finalized data to the Chairman of the IOC and the Project Leader. He will also supply a copy of the relevant data to each of the participants.

Terms of Reference of Radiosonde Comparison Expert

The Radiosonde Comparison Expert will be responsible for preparing advice for the local staff in Mauritius on the methods of performing successful radiosonde comparisons. He will be responsible for training the staff and advising the Project Leader on modifications to test procedures as the test proceeds. He will work with the participants to resolve issues such as radiofrequency interference between radiosonde types, problems with pre launch procedures, etc, as they occur.

- A. Before the intercomparison the Radiosonde Comparison Expert will:
1. Collaborate with the participants to ensure that the radiosondes used in the test are using radiosonde transmitters of sufficient stability that frequency drift during flight will be minimal. He will allocate the frequencies to be used by the different systems.
 2. He will prepare instructions for the local support staff from Mauritius in the handling and preparation of 2000g balloons.
 3. He will agree a suitable flight rig for supporting the radiosondes suspended from the balloons using materials readily available in Mauritius.
 4. He will liaise with the Project Manager in identifying the amount of hydrogen gas to be procured in order to complete the proposed test schedule.
- B. During the test the Radiosonde Comparison Expert will:

1. Work with the Project Manager in supervising the practical aspects of preparing the balloons, making the radiosonde flight rigs, launching the rigs and other associated practical duties.
2. He will ensure that the pre launch check procedures agreed by the Project team are performed effectively.
3. He will ensure that surface data input to the various systems are consistent.
4. He will act as back up to the Data Manager in supervising the collection and input of data to the intercomparison data base.
5. He will check that any additional remote sensing instrumentation deployed at the site for the test is functioning correctly.
6. Radiosonde Comparison Expert will also assist Data Manager in performing his duties.

Terms of Reference of Chair of IOC

The chairman of the IOC will support the comparison test by providing support and advice in areas where detailed knowledge of radiosonde test procedures and radiosonde error modes are essential for the successful outcome of the test.

- A. Before the test begins he will:
 1. Review preparations with the Project Manager and check that all necessary preparations are in hand.
 2. Develop the detailed flight programme for the intercomparison in liaison with the Project Manager and Radiosonde Comparison Expert; once the details of the participating radiosondes are submitted by the participants in November 2004.
 3. Advise on whether requests for changes by participants in the Programme agreed by the IOC in Geneva are acceptable. This may involve contacting the IOC members if the change requested is likely to cause significant modifications to the agreed test procedures/ scope of the test.
- B. During the intercomparison, he will:
 1. Resolve any difficulties that may occur because of disputes between the participants. In particular, if one participant feels that another participants system is interfering with and degrading the performance of his system.
 2. Provide an expert advice on whether problems with individual radiosonde systems are inherent to the type of radiosonde system, or are being caused by the specific conditions of the test.
 3. Resolve the problems related to short term variations, due to the fast response temperature sensors in the stratosphere, and decide whether these are caused by the flight conditions (e.g. the radiosondes measuring the balloon wake from time to time) or whether these are the result of poor methods of mounting the radiosondes on the radiosonde, or self heating of the temperature sensors. The IOC chairman will take responsibility for working with the participants and Project Manager to gain better insight into this problem, with possible minor modifications to radiosonde supports/position on the flight rig from time to time.
 4. Lead the data review meetings attended by all participants which will be held at least once per week during the intercomparison.
 5. Support the Project Manager in preparing the initial Executive Summary shortly after the test is completed.