

WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR INSTRUMENTS AND METHODS OF OBSERVATION

JOINT

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

AND

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

Geneva, Switzerland

28-30 November 2005

FINAL REPORT



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EXECUTIVE SUMMARY

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

The ET/IOC discussed and agreed on the Final Report of the WMO Intercomparison of High Quality radiosonde Systems held in Vacoas, Mauritius in February 2005. The Final Report provides factual information as well as scientific discourse of the intercomparison results thus becoming a valuable source of information for the whole range of readers, from staff employed in the operation of the upper-air networks, through managers to scientific personnel and private manufacturing industry. It is expected that the intercomparison will significantly contribute to further improvements in radiosonde performance.

ET/IOC agreed that the follow-up WMO Regional Intercomparisons of Radiosonde Systems should be organized within next 2-4 years to link the High Quality radiosondes with other radiosondes used predominantly in certain regions. A preliminary plan was made to hold the regional intercomparison in China in 2007.

The ET/IOC discussed the status and possible future development of the Interoperable Upper-Air Systems. It agreed that International Met Systems, on behalf of the HMEI, would prepare a discussion document/guidance for the Fourteenth session of the Commission for Instruments and Methods of Observation.

The progress in the development of the performance measures to demonstrate continuous improvement in the quality of UA observation was presented to the ET/IOC. The study demonstrates that a significant improvement in the quality, over last two decades, of temperature and geopotential height biases at 10 hPa from, typically from more than 3 degree C of discrepancy down to better than 0.5 degree C for temperature, and respectively from more than one thousand meters down to less than 20 m for geopotential heights.

The ET/IOC was informed on the results of intercomparison between the NASA ATM radiosonde, Modem, InterMet and Sippican radiosondes and on the partial results in satellite-derived temperature and humidity profiles based on GPS occultation measurements by the CHAMP satellite.

GENERAL SUMMARY

1. ORGANIZATION OF THE SESSION

1.1 Opening of the session

1.1.1 The second session of the Joint Meeting of the Expert Team on Upper-Air Systems Intercomparisons (ET) and International Organizing Committee on Upper-Air Systems Intercomparisons (IOC) was held in Geneva, Switzerland, 28-30 November 2005. Dr John Nash, vice-president of CIMO and Chairman of the ET and IOC, opened the session. The list of participants is given in Annex I.

1.1.2 Following the opening of the session, Prof. Hong YAN, Deputy Secretary-General, welcomed the participants to Geneva. In his statement to the ET and IOC, he recalled that despite various new remote-sensing techniques of upper-air sounding, the conventional radiosonde measurements would remain, for many years to come, the backbone of the upper-air observing network and that the intercomparisons of radiosondes are essential for high quality upper-air observations, their compatibility and their long-term stability.

1.1.3 The Deputy Secretary-General thanked the Mauritius Meteorological Services, manufacturers and the WMO project team for all the arrangements made and the hard work carried out for the success of the WMO Intercomparison of High Quality Radiosonde Systems held in Vacoas, Mauritius, 1-27 February 2005. He wished participants a productive meeting and an enjoyable stay in Geneva.

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

1.2 Adoption of the agenda

1.1.5 The ET/IOC adopted the Agenda for the meeting, which is reproduced at the beginning of this report.

1.3 Working arrangements for the session

1.1.6 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 last meeting in March 2004. He pointed out that the activities of the team were concentrated on the preparation of, and carrying out the WMO Intercomparison of High Quality Radiosonde Systems in Mauritius, February 2005. After the field exercise, substantial time was devoted to analysis of the results and preparation of the preliminary reports.

2.2 The chairman stressed the fact that the WMO project team was too small to cope with the scale of this intercomparison and that new procedures would be needed to address the capacities needed for the organization of future intercomparisons. He pointed out that for the first time a remote sensing component was attached to the intercomparison, supported by the European COST office. The remote sensing component significantly enhanced the quality treatment of the radiosonde data. Lessons were learned on the combined operation of remote sensing systems and radiosonde soundings, which are important for the future of integration of systems.

3. WMO INTERCOMPARISON OF HIGH QUALITY RADIOSONDE SYSTEMS

The preliminary temperature results show that the best radiosondes agreed to within ± 0.3 K from the surface to 31 km; the GPS height measurements give geopotential heights that are more accurate than the best pressure sensors at all heights above 16 km; for the relative humidity (RH) range 60-100 per cent, the more reliable RH sensors agreed to within ± 5 per cent on average for all heights from the surface to 11 km (-40 degrees Celsius) at night; and the typical random errors in wind component [u,v] measurements were less than or equal to 0.3 ms^{-1} for most systems at all heights. Although differences in performance of participating radiosonde systems were noted, all of them fall under the category of the High Quality radiosondes and thanks to the intercomparison there is now traceability from one system to another. The objectives of the intercomparison were achieved and the preliminary results clearly show the big leap forward made by the manufacturing industry in meeting the WMO requirements.

3.1 The chairman of the ET/IOC with the assistance of the Mauritius project team members prepared the draft version of preliminary report of the intercomparison for the discussion at the CIMO ET on Remote Sensing Upper-Air Technology and Techniques, Geneva, 14-17 March 2005 and for comments for the participating manufacturers. A preliminary report was then presented during the WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation (TECO-2005) and the Exhibition on Meteorological Instruments, Related Equipment and Services (METEOREX-2005), Bucharest, Romania, 4-7 May 2005, and published as the IOM Report No. 82.

3.2 Taking into account the proposals from manufacturers and other contributors, the graphical presentation of results was changed and an updated report was presented during the AMS Symposium on Instruments and Methods of Observation, Savannah, Georgia, June 2005.

3.3 The draft Final Report for the discussion of the ET/IOC took over the presentation of results from previous versions and was expanded by detailed scientific discourse of the presented results thus becoming a valuable source of factual and scientific information for the whole range of readers, from staff employed in the operation of the upper-air networks, through managers to scientific personnel and private manufacturing industry. Similarly to the outcome of the WMO Intercomparison of GPS Radiosonde, Brazil, 2001, it is expected that further improvements in radiosonde performance will be done within next 2-4 years. ET/IOC members, invited experts, Hydro-Meteorological Equipment Industry Association (HMEI) representatives and participating manufacturers congratulated the ET/IOC chairman for all his efforts and for the excellent report.

3.4 The comments presented by ET/IOC members, invited experts, HMEI representatives and participating manufacturers were discussed and incorporated in the Draft Final Report.

3.5 No additional proposals were made to Data policy to that already agreed at the 1st session of the ET/IOC.

3.6 The ET/IOC agreed on the Final Report that is presented in [Annex III](#). The Final Report will be published by WMO, at first on the CIMO/IMOP website and later as the IOM Report, and it will be distributed to WMO Members and participating manufacturers. It is expected that a number of scientific papers will also be published on this subject. The complete intercomparison database will be kept by UK Met Office and WMO and will be available for further scientific studies.

4. FUTURE INTERCOMPARISONS

4.1 Following the WMO Intercomparison of High Quality Radiosonde Systems, Mauritius, 2005, the ET/IOC suggested that WMO Regional Intercomparisons would take place within next 2-4 years to link the High Quality radiosondes with other radiosondes used predominantly in certain regions.

4.2 Mr Guo, China, presented the Progress in Upper-Air Observation Network in China based on the L-band radar and electronic radiosonde system. Mr Guo requested to hold the regional intercomparison in China, under the auspices of WMO, with the participation of one or two High Quality Radiosonde Systems to ensure the quality and data compatibility of their upper-air data. A preliminary plan was made to hold this intercomparison in 2007.

5. WORK PLAN

5.1 The outcome of the discussion on the above agenda items was recast into an updated 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.

6. OTHER BUSINESS

6.1 Interoperable Upper-Air Systems

6.1.1 Following the request of the WMO Executive Council to encourage radiosonde systems providers to develop interoperable systems, International Met Systems, a member of the HMEI, was requested to investigate the feasibility of interoperability in upper-air sounding systems and to present a paper on this topic to ET/IOC.

6.1.2 The presented paper summarized experience of InterMet in manufacturing interoperable 1680 MHz systems, a demonstration test of which was done under the auspices of CIMO in Dar-es-Salaam, Tanzania, 2004, and also presented a discussion on whether interoperability can be extended to 403 MHz GPS type sounding systems.

6.1.3 It was agreed that a paper on the feasibility of Interoperable upper-air systems covering the aspects of system design, standardization, cost implication, benefits, concerns and risk assessment should be presented to the CIMO-XIV session to provide advice to members.

6.1.4 Mr Clowney, International Met Systems, agreed to prepare a discussion document on behalf of the HMEI and submit it to the Secretariat in March 2006. It should take advantage of knowledge available with other manufacturers and Meteorological services, especially Météo France that works on a design of the 403 MHz GPS interoperable systems. The document would then be assessed by the ET/IOC and would constitute a basis for the presentation on this issue to the CIMO-XIV, December 2006.

6.2 Performance measures to demonstrate continuous improvement in the quality of upper-air observations

6.2.1 At the last ET/IOC meeting, Geneva, 17-20 March 2004, Messrs Bertrand Calpini and Carl Bower were tasked with "Development of performance measures to demonstrate the continuous improvement in the quality of upper-air observations".

6.2.2 Mr Calpini reported on the result of the work on this task. He expressed his warmest thanks and gave full credit to the work performed by Pierre Jeannet at MeteoSwiss for his major contribution on this report.

6.2.3 This report focuses on the study of the time evolution of selected statistical parameters reported in the different WMO radiosonde intercomparisons, namely, 1984 in the UK (phase I), 1985 in the USA (phase II), 1989 in the former USSR (phase III), 1993 in Japan (phase IV), 1995 in USA (Phase V), 2001 in Brazil (phase VI), and 2005 at Mauritius (phase VII).

6.2.4 The statistical parameters (systematic biases, standard deviations, etc) based on differences between the measurements obtained with different types of radiosondes for simultaneous measurements and the "link radiosondes" are used as a valuable tool for comparison

over the last two decades. Another possible approach where the different sondes are directly “inter-compared”, without using the link sonde, has also been used, while not showing significant improvement in the final results presented during the session. This second approach will not be further applied.

6.2.5 As the first example, the systematic temperature differences at 10 hPa at night are shown in Figure 1. The horizontal axis is a time axis covering the last 25 years. On the vertical axis, the bias values are reported against the link sonde for each measurement campaign individually, thus reflecting the changes and improvement over time of these results. The standard deviations of the biases are reported for each comparison.

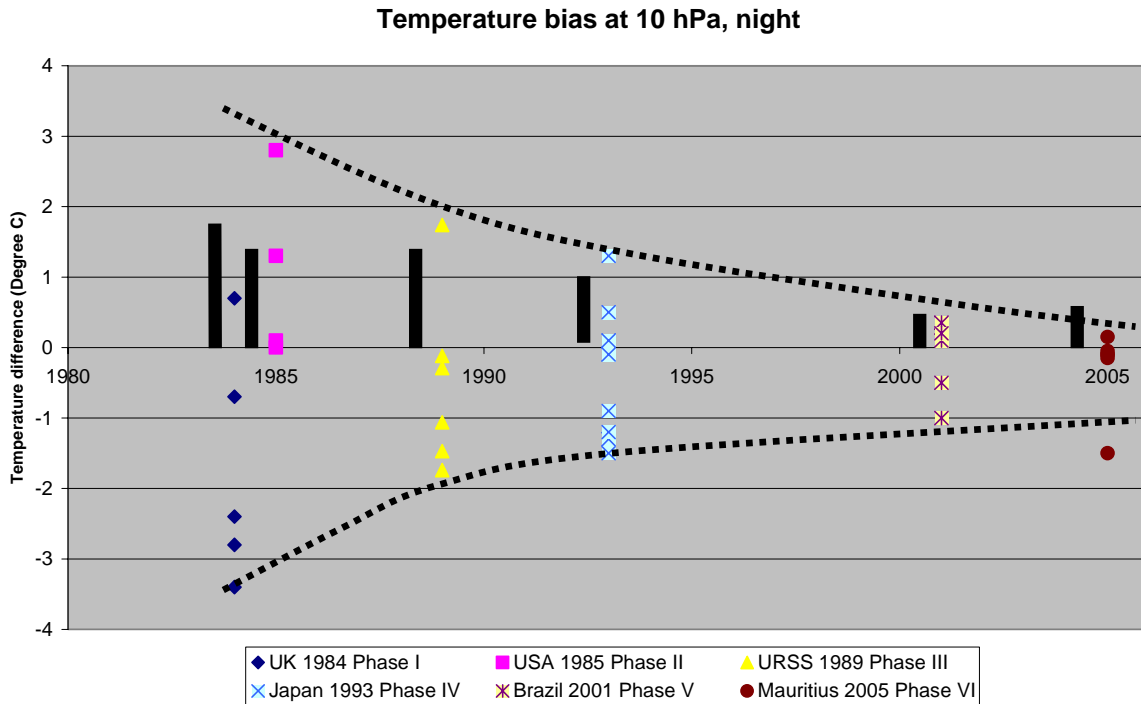


Figure 1. Nighttime temperature bias at 10 hPa for the six WMO Radiosonde Comparisons (simultaneous measurements). The dotted lines represent a qualitative envelope of all individual results, considering the first two Comparisons as a single one. The vertical full bars correspond to one standard deviation of the biases of each comparison.

6.2.6 As another important “final product” of this report, B. Calpini underlined the impressive jump in the quality of the radiosonde measurements over the last two decades when considering the geopotential height information. The Figure 2 below is also extracted from the report, and is proposed to be added in the final report of the Mauritius Island 2005 experiment, in the concluding remarks, as a demonstrator of this improvement over the years. It should be noted that it is only during Phase VI that the first GPS radiosondes were introduced; during Phase VII (Mauritius) most of the producers have integrated this development into their operational sondes.

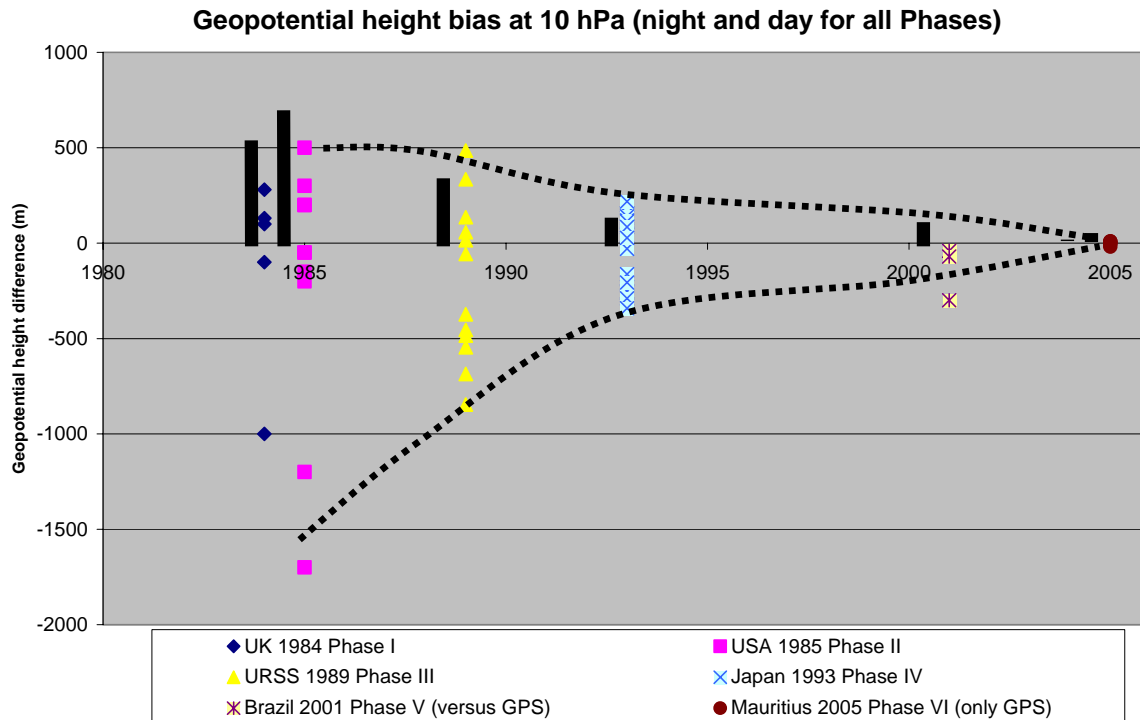


Figure 2. Bias of the geopotential altitude at 10 hPa for the six WMO Radiosonde Comparisons (simultaneous measurements). The two dotted lines represent a qualitative envelope of all individual results, considering the first two Comparisons as a single one. The vertical full bars correspond to one standard deviation of the biases of each comparison.

6.2.7 In both cases (temperature and geopotential height biases studied over the last two decades), the different radiosondes used worldwide clearly demonstrated a significant improvement “on average”, typically from more than 3 degree C of discrepancy down to better than 0.5 degree C for temperature (at 10 hPa), and respectively from more than one thousand meters down to less than 20 m for geopotential heights.

6.2.8 The ET/IOC expressed satisfaction with the work done so far on this item and recommended to:

- Focus only on the different IOM field campaigns,
- Add some historical background and pictures of radiosondes and sensors that help demonstrate the huge changes in the radiosonde technology over the last decades.
- Finalize this report by 31 March 2006.

6.3 Recent comparison results between the NASA ATM radiosonde, Modem, InterMet, and Sippican radiosondes

6.3.1 During October and November 2005 a series of comparison flights were made with the objective of quantifying the error of Modem and InterMet radiosondes. Consequently, comparison results between ATM radiosonde “true” temperature and Sippican chip thermistor were addressed. The success of the ATM radiosonde in producing an accurate (ambient) temperature profile depends on diversity between thermistors of different emissivity and absorptivity. Five thermistors (two white, one black and two aluminium) allow 4 solutions. The key is that the four profiles must agree within ~0.2 degree Celsius.

6.3.2 Additional flights between the ATM with the Sippican rod thermistor and ATM with Sippican 0.25 mm diameter bead thermistor were presented and showed that although a white rod and the white bead relation to "truth" were different, the two "true" temperatures derived from either thermistor agreed.

6.3.3 The results of the Modem and InterMet test showed that although corrections applied in Modem processing were good, additional correction is needed. Tests with InterMet uncorrected temperatures agreed closer to the ATM "truth" but corrections are still needed for the daytime and nighttime temperature measurements.

6.3.4 Sippican chip measurements relative to ATM temperature also required additional corrections both in daytime and nighttime.

6.4 Satellite-derived temperature and humidity profiles based on GPS occultation measurements by the CHAMP satellite

6.4.1 Mr Richner, Switzerland, made a presentation on the satellite-derived profiles based on GPS measurements by CHAMP satellite. The project, supported by the COST, complemented the WMO Intercomparison of High Quality Radiosonde Systems, Mauritius, 2005. The COST supervised the logging of all the remote sensing data, i.e., data from the ceilometer, cloud radar, GPS and the CHAMP satellite occultation measurements. The final work is in the process of assembling a database at the Institute for Atmospheric and Climate Science, ETH Zurich. It will contain all remote sensing data and can be accessed using an Internet browser. In addition, Mr Richner computed mean profiles for each of the multiple ascents, using a combination of those radiosondes that subjectively agreed best. These profiles are available both in graphical and numerical form. All data files will be complemented by an appropriate description of the contents and formats.

6.4.2 There were a total of 27 temperature and humidity profiles derived from the CHAMP satellite. The separation between density (i.e. temperature) and humidity effect on the total GPS delay observed by the satellite was made by using an iterative process, i.e., without resort to any other system or data. These profiles were kindly provided by the colleagues from the GeoForschungsZentrum Potsdam.

6.4.3 The study is expected to show whether humidity information in the upper troposphere and the lower stratosphere can be improved by combining radiosonde and satellite information. The observed radiosonde temperature profiles could be used when deriving the humidity profile from the occultation measurements, thus eliminating an inherent ambiguity. However, it must be born in mind that satellite data is averaged over a very large area (not necessarily centered at the location where the radiosonde ascent was made), while the radiosonde provides a local profile. On the other hand, the fact that the spatial variability of the atmosphere decreases with height alleviates the problems arising from this fact.

7. DRAFT REPORT OF THE SESSION

7.1 The members of Expert Team and International Organizing Committee prepared their inputs for the Final Report, a draft of which was subsequently prepared by the Secretariat. The meeting requested Secretariat to allow two more weeks for additional comments, if any, before publishing this report.

8. CLOSURE OF THE SESSION

11.1 The session was closed on 30 November 2005 at 17h00.

ANNEX I

List of participants

Dr John NASH ET Chair	The Meteorological Office FitzRoy Road Exeter Devon, EX1 3PB United Kingdom Tel.: +44 139 2 88 56 49 Fax: +44 139 2 88 56 81 E-mail: john.nash@metoffice.gov.uk
Mr Yatian GUO	China Meteorological Administration 46 Zhongguancun Nandajie Beijing 100081 China Tel.: +8610 6840 8242 Fax: +8610 6217 9786 quoyt@cma.gov.cn
Mr Yvan LEMAITRE	Météo-France DSO/DOA 42 Av. Coriolis 31057 Toulouse France Tel.: +33 5 67 69 87 70 Fax: +33 5 67 69 87 69 E-mail: yvan.lemaitre@meteo.fr
Dr Beenay PATHACK	Meteorological Services St Paul Road Vacoas Mauritius Tel.: +(230) 686 1031 / 32 Fax: +(230) 686 1033 E-mail: meteo@intnet.mu bpathack@mail.gov.mu
Mr Henk KLEIN BALTINK	Royal Netherlands Meteorological Institute Wilhelminalaan 10 P.O. Box 201 NL-3730 AE de BILT Netherlands Tel.: +(31 30) 2206 476 Fax: +(31 30) 2210 407 E-mail: Henk.Klein.Baltink@knmi.nl

Mr Carl A. BOWER	Observing Services Division Office of Climate, Water and Weather Services National Weather Service National Oceanic and Atmospheric Administration 1325 East-West Highway, No 4312 Silver Spring, MD 20910-3283 USA Tel.: +(1 301) 713 0722 Ext.145 Fax: +(1 301) 713 2099 E-mail: Carl.Bower@noaa.gov
Invited experts:	
Mr Richard SMOUT	Met Office Discovery 1-21 FitzRoy Road Exeter Devon EX1 3PB United Kingdom Tel.: +44 1392 88 5641 Fax: +44 1392 88 5681 E-mail: Richard.Smout@metoffice.gov.uk
Mr Rainer DOMBROWSKY	Office of Operational Systems National Weather Service National Oceanic and Atmospheric Administration 1325 East-West Highway, OPS1 Silver Spring, MD 20910-3283 USA Tel.: (202) 282 9937 Fax: (202) 282 8782 E-mail: Rainer.Dombrowsky@noaa.gov
Dr Bertrand CALPINI	MétéoSuisse Measurement Technical Department Aerological Station Payerne CH-1530 Payerne Switzerland Te.l: +(41 26) 662 6211; 662 6228 Fax: +(41 26) 662 6212 E-mail: bertrand.calpini@meteoswiss.ch
Mr Sergey KURNOSENKO	9334 Tovito Drive Fairfax Virginia 22031 USA Tel.: +(1 703) 591 1696 Fax: +(1 509) 752 2199 E-mail: skurnosenko@cox.net

Mr Francis J. SCHMIDLIN	NASA/GSFC/Upper-Air Instrumentation Research Project NASA/GSFC/WALLOPS Flight Facility Wallops Island, Instrument Sciences Branch (614.0) Virginia 23337 USA Tel: +1 757 8241618 Fax: +1 757 824 1036 E-mail: FJS@osb.wff.naa.gov
Prof. Hans RICHNER	Institute for Atmospheric and Climate Science ETH Zentrum CHN CH-8092 Zurich Switzerland Tel: +41 44 633 2759 Fax: +41 44 633 1058 E-mail: hans.richner@ethz.ch
Instrument Manufacturers:	
Mr Tom Curran	Lockheed Martin Sippican, Inc. Seven Barnabas Road Marion, MA 02738 USA Tel.: +(1 610) 397 0183, Ext.1 Fax: +(1 610) 397 8647 E-mail: tomas.curran@lmsco.com
Mr Hannu Jauhiainen	Vaisala Oyj P.O.Box 26 FIN-00421 Helsinki Finland Tel.: +(358 9) 8949 518 Fax: +(358 9) 8949 2564 E-mail: hannu.jauhiainen@vaisala.com
Mr Rémy Pepin	MODEM Z.A. De l'Orme à bonnet 91750 CHEVANNES France Tel: +(33 1) 6499 7752 Fax: +(33 1) 6499 7753 E-mail: rpepin@meteomodem.com
Mr Florian Schmidmer	GRAW Radiosondes GmbH Muggenhofer Street 95 90429 NUERNBERG Germany Tel.: +(49 911) 3201-0 Fax: +(49 911) 3201 150 E-mail: Fschmidmer@graw.de

Mr Shinichi Tsuda	MEISEI Electric Co. Ltd. 2 – 5 – 7, Koishikawa BUNKYO-KU Tokyo 112-8511 Japan Tel.: +(81 3) 3814 5112 Fax: +(81 3) 3814 5186 E-mail: tsudas@meisei.co.jp
Mr Makoto Fujita	MEISEI Electric Co. Ltd. 2223 Naganuma-cho Isesaki City, Gunma 372-8585 Japan Tel.: +(81 270) 32 0992 Fax: +(81 270) 32 0988 E-mail: juijitam@meisei.co.jp
Mr Paul Ruppert	Meteolabor AG Hofstrasse 92 CH-8620 WETZIKON Switzerland Tel: +(41 44) 934 40 40 Fax: +(41 44) 934 40 99 E-mail: paul.ruppert@meteolabor.ch
Mr Bruce Sumner	HMEI Executive Secretary HMEI Secretariat c/o WMO Tel.: +(41 22) 730 8334 Fax: +(41 22) 730 8340 E-mail: hmei@wmo.int
Mr Frederick A. Clowney	International Met Systems 4460 40th St. SE Grand Rapids MI 49512 USA Tel.: +618 285 7810 Fax: +616 957 1280 E-mail: fclowney@intermetsystems.com
Ms Christine Charstone	HMEI Administrator HMEI Secretariat c/o WMO Tel.: +(41 22) 730 8334 Fax: +(41 22) 730 8340 E-mail: hmei@wmo.int
WMO Secretariat 7 bis, avenue de la Paix CH-1211 Geneva 2 Switzerland	WWW website www.wmo.int/web/www/www.html

Dr Miroslav Ondráš

Senior Scientific Officer
Observing System Division
World Weather Watch Department
Tel.: +(41 22) 730 8409
Fax: +(41 22) 730 8021
E-mail: MOndras@wmo.int

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.06
Frank Schmidlin		a. GPS Radiosonde Comparison – Brazil	Jan.06			
		b. Radiosonde Relative Humidity Sensors Intercomparisons – Russia/USA 1995-1997	Done			
		c. Summary of the first five WMO Radiosonde Comparisons	Mar.06			
	2. Analysis of benefits from including remote sensing systems	Apr.06	<ul style="list-style-type: none"> • Report on Benefits from inclusion of remote sensing systems 	May.06		
	3. Planning for intercomparisons of candidate systems	Feb.06	<ul style="list-style-type: none"> • Publication of new proposed working “reference” for future radiosonde comparisons 	May.06		
			<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	May.06 May.06	<ul style="list-style-type: none"> • Report for TECO on Recommendation for testing of new types of radiosondes • Annual reports on radiosonde testing 	May.06 End of each calendar year.
1 c)	Review procedures of publication of results of WMO Radiosonde Comparisons	Yvan LEMAITRE Carl BOWER	1. Develop procedures of publication of results of WMO Radiosonde Comparisons 2. All ET members	May.06	<ul style="list-style-type: none"> • Report on Reference procedures for radiosonde intercomparisons • Proposal for update of CIMO Guide 	May.06 Oct.06
1d)	Review policy for data processing in WMO Intercomparisons	Frank Schmidlin	1. Develop procedures for data processing in future WMO Intercomparisons and tests	Jan.06	<ul style="list-style-type: none"> • Report on agreed policy for data processing in future WMO Intercomparisons and tests 	Mar.06
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,	Done Done	<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	Done Done		
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 	Done	<ul style="list-style-type: none"> • IOM Report on Global criteria for tracing the improvements of radiosondes 	Apr.06
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	Done	<ul style="list-style-type: none"> • CIMO Guide updated 	Nov.05

**Final Report
WMO Intercomparison of High Quality Radiosonde Systems, Mauritius, 2005**

See: <http://www.wmo.int/web/www/IMOP/reports.html>