Fiducial Reference Measurements for validation of Surface Temperature from Satellites (FRM4STS): Water Surface Temperature Measurements

ESA Contract No. 4000113848_15I-LG

D-90B: Implementation plan for the FRM4STS LCE (LCE-IP)

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Fiducial Reference Measurements for validation of Surface Temperature from Satellites (FRM4STS): Water Surface Temperature Measurements.

D90-B: Laboratory Calibration Experiment Implementation Plan (LCE-IP)

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CONTENTS

DOCUMENT MANAGEMENT

Issue	Revision	Date of Issue/revision	Description of Changes
1	1	14.09.2015	Creation of document
1	2	01.10.2015	Complete draft submitted for review
1	3	04.07.2018	Revised draft submitted for review
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DOCUMENT APPROVAL

Contractor Approval

Name	Role in Project	Signature & Date (dd/mm/yyyy)
Dr Nigel Fox	Technical Leader	
Dr Andrew Brown	Project Manager	Andrew Brown, NPL 22 August 2018

CUSTOMER APPROVAL

Name	Role in Project	Signature	Date (dd/mm/yyyy)
C Donlon	ESA Technical Officer		

APPLICABLE DOCUMENTS

AD Ref.	Ver. /Iss.	Title
EOP-SM/2642	1	Fiducial Reference Measurements for Thermal Infrared Satellite Validation (FRM4STS) Statement of Work for Water Field Measurements

ACRONYMS AND ABBREVIATIONS

CEOS	Committee on Earth Observation Satellites
DMI	Danish Meteorological Institute
FRM4STS	Fiducial Reference Measurements for
GOTA	Grupo de Observacion de la Tierra y la Atmosfera
IPL	Imaging Processing Laboratory
IR	Infra-Red
ISO	International Organization for Standardization
JPL	Jet Propulsion Laboratory
KIT	Karlsruhe Institute of Technology
LST	Land Surface Temperature
NMI	National Measurement Institute
NPL	National Physical Laboratory
OUC	Ocean University of China
PTB	Physikalisch-Technische Bundesanstalt
SST	Sea Surface Temperature
SI	Système Internationale
UK	United Kingdom
UTC	Coordinated Universal Time
WGCV	Working Group for Calibration and Validation
WST	Water Surface Temperature

1. INTRODUCTION

The measurement of the Earth's surface temperature is a critical product for meteorology and an essential parameter/indicator for climate monitoring. Satellites have been monitoring global surface temperature for some time, and have established sufficient consistency and accuracy between in-flight sensors to claim that it is of "climate quality". However, it is essential that such measurements are fully anchored to SI units and that there is a direct correlation with "true" surface/in-situ based measurements.

The most accurate of these surface based measurements (used for validation) are derived from field deployed IR radiometers. These are in principle calibrated traceably to SI units, generally through a blackbody radiator. Such instrumentation is of varying design, operated by different teams in different parts of the globe. It is essential for the integrity of their use, to provide calibration data for satellites both in-flight and to provide the link to future sensors, that any differences in the results obtained between them are understood. This knowledge will allow any potential biases to be removed and not transferred to satellite sensors. This knowledge can only be determined through formal comparison, of the instrumentation, both in terms of its primary "lab based" calibration and its use in the field. If a fully traceable link to SI can also be established and demonstrated this will ensure that the data will be robust and can claim its status as a "climate data record".

The IR calibration community is well versed in the need and value of such comparisons having held highly successful exercises in Miami and at NPL in 2001 and 2009 [1, 2]. However, six years will have passed since the last comparison and it is considered timely to repeat/update the process. This protocol describes the set of comparison activities that will be carried out as part of this exercise "in the field" on the surface temperature of a water reservoir.

2. OBJECTIVES

The overarching objective of this comparison is "*To establish the "degree of equivalence" between surface based IR Cal/Val measurements made in support of satellite observations of the Earth's surface temperature and to establish their traceability to SI units through the participation of national standards laboratories".*

The objective can be sub-divided into the following:

1) Evaluation of the differences in IR radiometer primary calibrations
    a. Reference standards used (blackbodies) and traceability
    b. Radiometers response to common blackbody target
    c. Evaluation of differences in radiometer response when viewing Water/Land surface targets, in particular the effects of external environmental conditions such as sky brightness.
2) Establishment of formal traceability for participant blackbodies and radiometers

The purpose of this document is to describe the implementation plan for the comparison of the performance of radiometers in the field, while viewing water surface targets.

3. ORGANIZATION

3.1 PILOT

NPL, the UK national metrology institute (NMI) will serve as pilot for this comparison supported by the University of Southampton and the RAL. NPL, the pilot, will be responsible for inviting participants and for the analysis of data, following appropriate processing by individual participants. NPL, as pilot, will be the only organisation to have access and to view all data from all participants. This data will remain confidential to the participant and NPL at all times, until the publication of the draft report showing results of the comparison to participants.

3.2 PARTICIPANTS

The list of the potential participants, based on current contacts and expectation who will be likely invited to take part is given in the Section 3.3. A full invitation to the international community through CEOS and other relevant bodies will be carried out to ensure full opportunity and encouragement is provided to all. All participants should be able to demonstrate independent traceability to SI of the instrumentation that they use, or make clear the route of traceability via another named laboratory. By their declared intention to participate in this key comparison, the participants accept the general instructions and the technical protocols written down in this document and commit themselves to follow the procedures strictly. Once the protocol and list of participants has been agreed, no change to the protocol or list of participants may be made without prior agreement of all participants.

3.3 PARTICIPANTS' DETAILS

NB: This is not the full list

Table 1. Participants' Contact Details

Contact person	Short version	Institute	Contact details
Nigel Fox	NPL	National Physical Laboratory	email: nigel.fox@npl.co.uk; Tel: +44 20 8943 6825
Carol Anne Clayson	Woods Hole Oceanographic Institution	266 Woods Hole Road, Woods Hole, MA 02543-1050 U.S.A	email: cclayson@whoi.edu; Tel: +1 508 289 3626
Jacob Høyer	DMI	Danish Meteorological Institute (DMI), Centre for Ocean and Ice, Lyngbyvej 100, 2100 København Ø	email: jlh@dmi.dk; Tel: +4539157203
Frank Goettsche	KIT	Institute for Meterology and Climate Research (IMK-AF), Kaiserstr. 12, 76131, Karlsruhe, Germany	email: frank.goettsche@kit.edu; +49 721 608-23821
Helen Beggs	Bureau of Meteorology, Australian Govt.	Ocean Modelling Research Team Research and Development Branch Bureau of Meteorology GPO Box 1289 Melbourne VIC 3001 Level 11, 700 Collins Street, Docklands VIC 3008	email: h.beggs@bom.gov.au; Tel: +61 3 9669 4394; Fax: +613 9669 4660
Nicole Morgan	CSIRO	Seagoing Instrumentation Team, Oceans and Atmosphere Flagship, CSIRO, GPO Box 1538, Hobart, TAS, 7001, AUSTRALIA	email: Nicole.Morgan@csiro.au; Ph: +613 6232 5222
Leiguan Ouc	OUC-CN	Ocean Remote Sensing Institute Ocean University of China 5 Yushan Road,Qingdao, 266003 China	email: leiguan@ouc.edu.cn

Contact person	Short version	Institute	Contact details
Manuel Arbelo	GOTA	Grupo de Observacion de la Tierra y la Atmosfera (GOTA), ULL, Spain	email.: marbelo@ull.es
Raquel Niclos			email.: Raquel.Niclos@uv.es
Simon Hook	JPL-NASA	Carbon Cycle and Ecosystems MS 183-501, Jet Propulsion Laboratory 4800 Oak Grove Drive, Pasadena, CA 91109 USA	email: simon.j.hook@jpl.nasa.gov
J. A. Sobrino	IPL	Imaging Processing Laboratory (IPL) Parque Científico,Universitat de Valencia Poligono La Coma s/n, 46980 Paterna Spain	Tel: +34 96 354 3115; email: sobrino@UV.es
Tim Nightingale	STFC	STFC Rutherford Appleton Laboratory Chilton, Didcot,Oxon OX11 0QX United Kingdom	Tel: +44 1235445914; Tim.Nightingale@stfc.ac.uk
Werenfrid Wimmer	Soton	National Oceanography Centre, Southampton,European Way, Southampton, SO19 9TX, United Kingdom	email: w.wimmer@soton.ac.uk
Willem Vreeling	DLR	DLR, Remote Sensing Technology Institute, Oberpfaffenhofen, D-82234 Wessling, Germany	email: willem.vreeling@dlr.de
Caroline Sloan	MOD, NAVY SHIPS-HM FEIO	Fleet Environmental Information Officer NAVY SHIPS-HM FEIO | Navy Command Headquarters, MP 2.3, Leach Building, Whale Island, Portsmouth, Hampshire, PO2 8B	Tel: 023 9262 5958 | Mil: 93832 5958; NAVYSHIPS-HMFEIO@mod.uk; caroline.sloan104@mod.uk
Ian Barton	CSIRO Australia	Head office, PO Box 225,Dickson ACT 2602 Australia www.csiro.au	Tel: +61 3 9545 2176; email: Ian Barton@csiro.au
Dr. César Coll	UV-ES	Dept. of Earth Physics and Thermodynamics Faculty of Physics, University of Valencia Dr. Moliner, 50. 46100 Burjassot Spain	email: Cesar.Coll@uv.es
Raju Datla	NIST	100 Bureau Drive, Gaithersburg, MD 20899 USA	email: rdatla@nist.gov
William (Bill) Emery	EDU-USA	Univ of Colorado, Aerospace Eng. Sci. Dept CB 431, Boulder,CO, 80309-0431 USA	email: emery@colorado.edu
Dr. Frank-M. Goettsche	IMK-FZK	Forschungszentrum Karlsruhe Institute of Meteorology and Climate Research, Atmospheric Trace Gases and Remote Sensing, Meteorological Satellite-Data Analysis, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen Germany	email: frank.goettsche@imk.fzk.de; Tel: +49-(0)7247-82-3821
Peter J Minnett	RSMAS	University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149 USA	email: pminnett@rsmas.miami.edu

3.4 FORM OF COMPARISON

This protocol covers a comparison which takes the form of all the radiometers observing a common entity, the surface of water in a water reservoir, and analysis will be made by reference to the mean value observed by all participants. In some cases, to remove potential systematic biases from the measurand under evaluation, results will undergo a normalisation.

3.5 COMPARISON OVERVIEW

The water surface temperature calibration comparison exercise consists of all radiometers simultaneously viewing the same part of the water reservoir from the platform in the middle of the Wraysbury reservoir for a variety of view angles: 40º, 45º, 50º and 55°. Measurements will be performed during both day and night time conditions.

3.6 TIMETABLE

There are three main phases to the comparison activity. The first phase prepares for the measurements; the second phase is the measurements themselves and the third phase the analysis and report writing.

Table 2. Comparison activity- Phases

PHASE 1: PREPARATION	
Invitation to participate	August 2015
Preparation and formal agreement of protocol	Jan - March 2016
PHASE 2: MEASUREMENTS	
Participants measure water surface temperature	June 2016
Participants send all data and reports to pilot	July 2016
PHASE 3: ANALYSIS AND REPORTS	
Participants send preliminary report of measurement system and uncertainty to pilot and forwarded to all	April 2016
Receipt of comments from participants	May 2016
Draft A (results circulated to participants)	July 2016
Final draft report circulated to participants	August 2016
Draft B submitted to CEOS WGCV	September 2016
Final Report published	October 2016

The table below shows the plan for the comparison activity. The first week starting on Monday 20th June 2016 has been allocated to laboratory measurements of the reference blackbody using the participants' radiometers as well as the measurement of the participants' blackbodies using the reference radiometers of NPL and PTB. These measurements are expected to last most of that week. If these measurements finish earlier than the end of the week, some field measurements of Land Surface Temperature (LST) can be done at a site near NPL. However, the plan is to start the LST measurements on Monday 4th July 2016 at a site near NPL. The LST measurements can continue to the end of that week, if necessary, but they are expected to finish by Wednesday 6th July.

The second week starting in on Monday 27th June 2016 has been allocated to field measurement of the water surface temperature of the large water reservoir at Wraysbury, near NPL. Measurements will be done from the platform located in the middle of the reservoir. These measurements are expected to finish by the end of that week (Friday 1st July 2016).

Although all participants are encouraged to participate in all three activities, only the laboratory calibration of the participants' radiometers and blackbodies is considered mandatory to all participants.

The measurements on the Wraysbury reservoir and LST measurements near NPL may be omitted by participants who do not consider them as their remit. In those cases it may be possible to arrange for some LST measurements to take place in parallel to the Water body comparison.

Table 3. Comparison Activity- Plan

Week No.	Experiment No.	Start Date	End Date	Experiment	Venue
1 Compulsory	1	20 JUNE 2016	24 JUNE 2016	Laboratory calibration of participants' radiometers against reference blackbody. Simultaneously, laboratory calibration of participants' blackbodies using the NPL AMBER facility and PTB's IR radiometer.	NPL, UK
2 Optional	2	27 JUNE 2016	1 JULY 2016	Water surface temperature measurement inter-comparison of participants' radiometers.	Wraysbury reservoir, near NPL, UK
3 Optional	3	04 JULY 2016	08 JULY 2016	Land Surface Temperature measurements inter-comparison of radiometers	Near NPL, UK

3.7 TRANSPORTATION OF INSTRUMENTATION

It is the responsibility of all participants to ensure that any instrumentation required by them is shipped with sufficient time to clear any customs requirements of the host country, in this case the UK. This includes transportation from any port of entry to the site of the comparison and any delay could result in them being excluded from the comparison. NPL can provide some guidance on the local processes needed for this activity.

It is recommended that where possible any fragile components should be hand carried to avoid the risk of damage.

The pilot and host laboratory have no insurance for any loss or damage of the instrumentation during transportation or whilst in use during the comparison, however all reasonable efforts will be made to aid participants in any security.

Electrical power (220 V ac) will be available to all participants, with a local UK plug fitting.

3.8 PRELIMINARY INFORMATION

Three months prior to the start of the comparison participants will be required to supply to the pilot a description of the instrumentation that they will bring to the comparison. This will include any specific operational characteristics where heights/mountings may be critical as well as a full description of its characterisation, traceability and associated uncertainties under both laboratory and field conditions. These uncertainties will be reviewed by NPL for consistency and circulated to all participants for comment and peer review. Submitted uncertainty budgets can be revised as part of this review process but only in the direction to increase the estimate in light of any comments. No reduction will be allowed for the purposed of this comparison but post the comparison process participants may choose to re-evaluate their uncertainties using methods and knowledge that they may acquire during the review process.

4. MEASUREMENT INSTRUCTIONS

4.1 TRACEABILITY

All participant instruments should be independently traceable to SI units with documentary evidence of the route and associated uncertainty. If this traceability is provided as part of a "calibration" from the instrument manufacturer then the manufacturer should be contacted and asked to supply the appropriate details.

4.2 MEASUREMENT WAVELENGTHS

The comparison will be analysed as a set of comparisons for each wavelength where appropriate or as wavelength band e.g. 3 to 5 μm and 8 to 12 μm. Participants must inform the pilot laboratory prior to the start of the comparison which wavelengths the participant will be taking measurements at.

4.3 MEASURAND

The principle measurand in this comparisons is brightness temperature.

4.4 MEASUREMENT INSTRUCTION

4.4.1 Water surface Temperature Comparison of Radiometers

This will involve a set of measurements at a range of angles in two stages i.e. day and night.

4.4.1.1 Day-time measurements

- Each participant radiometer should be mounted on the platform in the middle of Wraysbury reservoir and aligned to view the area indicated by the pilot. This target location will be chosen to allow comparisons to be made at a range of view angles.

- The "clock" of each participant should be synchronised to that of UTC.

- Following an indication from the pilot, each participant will then measure the target and record its viewed brightness temperature (Water and Sky as correction) and at all wavelengths at time intervals to suit each radiometer. The effective time of each observation should be clearly indicated.

- The host will collect measurements of meteorological data and bulk water temperature, time stamped during this process.
- Participants will be encouraged to change viewing angle during the measurements period.
- After completing the above measurement sequence, participants will have 3 hours to carry out any necessary post processing e.g. sky brightness correction etc before submitting final results to the pilot, which will include processed Water Surface Temperature (WST) values.
- The results should not be discussed with any participant other than the pilot until the pilot gives permission.

4.4.1.2 Night-time measurements

- The same measurements can be taken during night-time under unattended operation.
- Night time measurements will be made under unattended operation of the radiometers.

4.4.2 Declaration of Comparison completion

The above process should ideally be considered as a single comparison and the results analysed. Before declaring the results to the participants the pilot will consult with all participants about the nature of the meteorological conditions of the comparison and with additional knowledge of the variance between declared results determine if a repeat should be carried out. At this stage participants may be told the level of variance between all participants but no information should be given to allow any individual result or pair of results to be determined. If the participants consider that the process should be repeated, as a result of poor conditions, then the results of that "day-night" will remain blind to the pilot.

The comparison process will be repeated until all participants are happy that meteorological conditions are good or that time has run out. At this point the comparison will be considered final and the results provided to all participants. This will constitute the final results and no changes will be allowed, either to the values or uncertainties associated with them unless they can be shown to be an error of the pilot.

However, if a participant considers that the results that they have obtained are not representative of their capability and they are able to identify the reasons and correct it, they can request of the pilot (if time allows) to have a new comparison. This comparison, would require participation of at least one other participant and ideally two and sufficient time.

If the above conditions can be met then the above comparison process can be repeated.

4.4.3 General

No other measurements are to be attempted by neither the participants nor any modification to the operating conditions during the course of this comparison. The transfer standards used in this comparison should not be used for any purpose other than described in this document nor given to any party other than the participants in the comparison during or following the comparison.

Any information obtained relating to the use or any results obtained by a participant during the course of the comparison shall be sent only to the pilot laboratory who will be responsible for co-ordinating how the information should be disseminated to other participants. No communication whatsoever regarding any details of the comparison other than the general conditions described in this protocol shall occur between any of the participants or any party external to the comparison without the written consent of the pilot laboratory. The pilot laboratory will in turn seek permission of all the participants. This is to ensure that no bias from whatever accidental means can occur.

5. MEASUREMENT UNCERTAINTY

The uncertainty of measurement shall be estimated according to the *ISO Guide to the Expression of Uncertainty in Measurement* (QA4EO-CEOS-DQK-006). In order to achieve optimum comparability, a list containing the principal influence parameters for the measurements and associated instrumentation are given below. An example table which should be completed by participants is included as Appendix C. The participating laboratories are encouraged to follow this breakdown as closely as possible, and adapt it to their instruments and procedures. Other additional parameters may be felt appropriate to include dependent on specific measurement facilities and these should be added with an appropriate explanation and/or reference. As well as the value associated with the uncertainty, participants should give an indication as to the basis of their estimate. All values should be given as standard uncertainties, in other words for a coverage factor of $k = 1$. Note this table largely refers to the uncertainties involved in making the measurement during the comparison process, and as such includes the summary result of the instruments primary traceability etc It is expected that the uncertainty associated with the full characterisation of the instrument will be presented in a separate document and also any differences for when used in Laboratory or field conditions. An example of such an analysis will be provided in the final protocol but some key components are listed below. Guidance on establishing such uncertainty budgets can be obtained by review of the NPL training guide http://www.emceoc.org/documents/uaeo-int-trg-course.pdf

Type A

Repeatability of measurement - repeatability of measurement process without re-alignment of the participants' instrument. This component should be largely caused by the instrumentation stability/resolution related to the output from the reference standard and any associated measuring instrument. In effect the standard deviation of a single set of measurements made on the reference standard. This should be presented as a relative quantity.

Reproducibility of measurement - reproducibility (run to run) following re-alignment of the instrument with the comparison transfer standard. This should be, largely caused by the measurement set-up related to the output from the transfer standard. This should be presented in terms of percentage of the assigned result.

Type B

Participants disseminated scale - This is the total uncertainty of the participant's instrument. This includes its traceability to any primary reference standard, underpinning scale as disseminated by them. This should include the uncertainty in the primary SI realisation, or in the case of a scale originating from another laboratory, the uncertainty of the scale disseminated to it by that laboratory. It should of course reference the originating laboratory. All uncertainties contributing to this parameter should be itemised as part of the report, or if published a copy of this publication attached. These should include spectral emissivity and its uniformity in the case of the black body, together with any thermometry.

Wavelength - This is the uncertainty in the absolute value of the wavelength used for the comparison. This should only be taken account of in terms of the instrumentation being used and should include details relating to bandwidth where appropriate.

6. REPORTING OF RESULTS

On completion of each set of results, as indicated above, they should be reported to the pilot. Where possible, these should be sent in electronic form as well as hard copy at the time of the comparison. In this way any immediate anomalies can be identified and potentially corrected during the course of the comparison whilst still keeping results blind.

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The measurement results are to be supplied in the Template provided by the pilot laboratory at the beginning of the comparison (see Appendix A) with the final draft of the protocol. The measurement report is to be supplied in the Word Template as a .doc file provided by the pilot. This will simplify the combination of results and the collation of a report by the pilot and reduce the possibility of transcription errors.

The measurement report forms and templates will be sent by e-mail to all participating laboratories. It would be appreciated if the report forms (in particular the results sheet) could be completed by computer and sent back electronically to the pilot. A signed report must also be sent to the pilot in paper form by mail or as a scanned document, receipt will be acknowledged, see Appendix D. In case of any differences, the paper forms are considered to be the definitive version.

If, on examination of the complete set of provisional results, ideally during the course of the comparison, the pilot institute finds results that appear to be anomalous, all participants will be invited to check their results for numerical errors without being informed as to the magnitude or sign of the apparent anomaly. If no numerical error is found the result stands and the complete set of final results is sent to all participants. Note that once all participants have been informed of the results, individual values and uncertainties may be changed or removed, or the complete comparison abandoned, only with the agreement of all participants and on the basis of a clear failure of instrumentation or other phenomenon that renders the comparison or part of it invalid.

Following receipt of all measurement reports from the participating laboratories, the pilot laboratory will analyse the results and prepare a first draft report on the comparison, draft A. This will be circulated to the participants for comments, additions and corrections.

7. COMPARISON ANALYSIS

Each comparison will be analysed by the pilot according to the procedures outlined in QA4EO-CEOS-DQK-004. In some cases, analysis will be carried out based solely on results declared by the participant, in others there will be further analysis based on modifications of the instrument calibration as a result of previous comparisons. In this way all available information will be presented and the final results will be transparent to all readers of the report.

Unless an absolute traceable reference to SI of sufficient accuracy is a-priori part of the comparison and accepted as such by all participants, all participants will be considered equal. All results will then be analysed with reference to a common mean of all participants weighted by their declared uncertainties.

8. REFERENCES

1. Barton, I. J., Minnett, P. J., Maillet K. A., Donlon, C. J., Hook, S. J., Jessup, A. T. and Nightingale, T. J., 2004," The Miami 2001 infrared radiometer calibration and intercomparison: Part II Shipboard results", *Journal of Atmospheric and Oceanic Technology*, 21, 268-283.

2. Theocharous, E., Usadi, E. and Fox, N. P., "CEOS comparison of IR brightness temperature measurements in support of satellite validation. Part I: Laboratory and ocean surface temperature comparison of radiation thermometers", NPL REPORT OP3, July 2010

APPENDIX A: MEASUREMENT RESULTS

The attached measurement summary should be completed by each participant for each completed set of laboratory measurements. A complete set being one, which may include multiple measurements on, or using the same instrument but does not include any realignment of the instrument. For each realignment a separate measurement sheet should be completed.

For clarity and consistency the following list describes what should be entered under the appropriate heading in the table.

Wavelength	The assigned centre wavelength of the measured brightness temperature. For the case of Fourier Transform spectrometers, the wavelength range and wavelength resolution should be specified.
Bandwidth	The spectral bandwidth of the instrument used for the comparison defined as the Full Width at Half the Maximum.
Brightness temperature	Measured or predicted brightness temperature by participant
Std Deviation	The standard deviation of the number of measurements made to obtain the assigned brightness temperature without realignment
Number of Runs	The number of independent measurements made to obtain the specified standard deviation.
Uncertainty	The total uncertainty of the measurement of brightness temperature separating this into Type A and B for a coverage factor of k=1.
Emissivity	The average spectral emissivity within the bandwidth
View angle from Nadir	The angle of view of the radiometer to the Ocean from Nadir

Field Measurement Results

Instrument Type ………… Identification Number ……… Ambient temperature …………

Day/time (UTC)	Brightness Temperature K	Wavelength μm	Bandwidth nm	Std Dev.	Uncertainty % A	B	No. of Runs

Participant: ………………………………………………………………………………………

Date: ………………Time (UTC)…………… Signature: ……………………………..

APPENDIX B: DESCRIPTION OF INSTRUMENTATION AND ROUTE OF TRACEABILITY

This template should be used as a guide. It is anticipated that many of the questions will require more information than the space allocated.

Make and type of Instrument (Radiometer and/or black body)...

....

Outline Technical description of instrument: *this could be a reference to another document but should include key characteristic: type of detector, spectral selecting component(s), field of view, type of black coating (and its spectral characteristics), model used to determine emissivity, location, number and type of thermometers….* ....

....

....

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....

....

Establishment or traceability route for primary calibration including date of last realisation and breakdown of uncertainty: *this should include any spectral characterisation of components/instruments* ....

....

....

Operational methodology during measurement campaign; *method of alignment, sampling strategy, data processing methods* ....

....

....

Radiometer usage (deployment), previous use of instrument, locations regularity, and planned applications, if activities have targeted specific mission please indicate
………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………

....

Participant: …………………………………………………………………………………

Date: ……………………………………… Signature: ………………………………..

APPENDIX C: UNCERTAINTY OF MEASUREMENT

The table below is a suggested layout for the presentation of uncertainties for the calibration of radiometers. It should be noted that some of these components may sub-divide further depending on their origin. The RMS total refers to the usual expression i.e. square root of the sum of the squares of all the individual uncertainty terms as shown in the example for Type A uncertainties.

Parameter	Type A Uncertainty in Value / %	Type B Uncertainty in Value / (appropriate units)	Uncertainty in Brightness temperature K
Repeatability of measurement	u_{Repeat}		u_{Repeat}
Reproducibility of measurement	u_{Repro}		u_{Repro}
Linearity of radiometer		u_{Lin}	u_{Lin}
Primary calibration		u_{Prim}	u_{Prim}
Drift since calibration		u_{Drift}	u_{Drift}
RMS total	$((u_{ref})^2+(u_{Trans})^2))^{½}$		

APPENDIX D: DATA RECEIPT CONFIRMATION

All data should be sent to the pilot NPL. The details of the contact person for this are:

To: **(participating laboratory, please complete)**

From: **Dr Theo Theocharous**
National Physical Laboratory
Hampton Road
Teddington
Middlesex
United Kingdom
TW11 0LW

Tel: ++44 20 8943 6977
e-mail: theo.theocharous@npl.co.uk

We confirm having received your data resulted from the CEOS key comparison of "techniques/instruments used for surface IR radiance/brightness temperature measurements" on ....(date).

....
....
....
Date:………………………………Signature:………………………….

-END OF DOCUMENT-