Final Publishable JRP Summary for ENV58 MeteoMet2
Metrology for Essential Climate Variables

Overview

An Essential Climate Variable (ECV) is a physical, chemical or biological variable that critically contributes to the characterisation of the Earth's climate. ECVs include water vapour in the atmosphere, surface and deep sea temperature, ocean salinity, air temperature, precipitation and soil moisture. Prior to this project, long-term, high-quality observations of these variables did not exist, yet they are vital as society becomes increasingly affected by climate change.

This project investigated the performance of sensors used to monitor climate variables under different conditions and produced new measurement methods, techniques and standards. The results will improve the monitoring of essential climate variables, which will benefit European industries such as agriculture, energy, and transport, and reduce the threat to public health.

Need for the project

As stated by the Global Climate Observing System (GCOS) '*Long-term, high-quality and uninterrupted observations of the atmosphere, land and ocean are vital for all countries, as their economies and societies become increasingly affected by climate variability and change'*. High-quality observations are possible only if they are based on a sustained traceability to the SI and with reliable uncertainties associated with the measured ECVs.

<u>Air</u>
Air humidity is a key parameter in climate processes. A big challenge, for humidity sensors, is the wide dynamic range with a factor of more than 10,000 of water content in the atmosphere. Reliable measurements require sensitive and fast responding sensors to quantify dynamic changes. Radiosonde sensor calibration protocols needed to be improved and validated, to cover real conditions. Radiosondes are small weather stations coupled with a radio transmitter, carried into the atmosphere by a weather balloon. They provide a method for measuring the vertical humidity profile in the troposphere and lower stratosphere, which is vital for weather forecasts and climate change monitoring.

<u>Sea</u>
Two of the key oceanic ECVs, for monitoring and understanding decadal changes in heat content and flow, are temperature and salinity. A comprehensive study of the effect of the main quantities of influence on thermometers and salinometers was needed, for reducing the measurement uncertainty and validating their characterisation.

<u>Land</u>
For land ECVs, consistent measurement uncertainty calculations need complete knowledge of the measurement system: its intrinsic behaviour, parameters of influence, and siting.

The World Meteorological Organisation/Commission for Instruments and Methods of Observation (WMO/CIMO) notices the '*importance of instrument intercomparison as a tool to improve the data traceability and the uncertainty calculation and to improve operational and maintenance procedures'*. Prior to this project, laboratory intercomparisons were not yet able to guarantee the full traceability and comparability of the data; furthermore, well-defined protocols were missing. The permafrost temperature is classified as a parameter for the investigation of climate changes, but prior to the work of this project, only a few or none of the measurement procedures reported a fully detailed uncertainty budget. Calibration and measurement standards for

EMRP
European Metrology Research Programme
Programme of EURAMET
The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

precipitation and soil moisture were not yet sufficiently developed to cope with the differences between laboratory setups and field conditions.

Building on the work of EMRP project ENV07 *Metrology for pressure, temperature, humidity and airspeed in the atmosphere* on the traceability to the SI of some ECVs and the evaluation of the calibration uncertainties, this project extends the investigations to additional variables and contributions to the uncertainty.

Scientific and technical objectives

1. Air

To improve the accuracy and traceability of humidity and temperature measurements in air

- Development of metrological procedures to calibrate radiosondes under atmospheric conditions including reduced pressures and temperatures.
- Measurement of humidity enhancement factors under atmospheric conditions.
- Development of spectroscopic techniques as standards for traceable humidity measurements and on-site references.
- Development of a traceable humidity source capable to provide on-site calibration to airborne instruments.
- Development of a reference instrument for the measurement of fast transients of temperature and humidity in free space.
- Development of traceable humidity sensors based on microwave resonators with low response time and small size.

2. Sea

To improve the accuracy and traceability of temperature measurements in oceans

- Development of facilities to study the pressure dependence of deep-sea thermometers and to establish validated pressure-correction models.
- To perform a thermodynamic calibration of deep-sea thermometers, to analyse the temperature-resistance linearisation models, to define the uncertainties or to propose improved models.
- Development of temperature sensors distributed along optical fibres by means of Bragg-gratings to improve the traceability of sea-surface and sea-profile temperature measurements and to monitor temperature drifts of the thermometers in underwater observatories.

To improve the accuracy and traceability of salinity measurements in oceans

- Development of a facility for determining temperature and pressure effects on salinometers based on the measurement of the seawater refraction index and to characterise them metrologically.

3. Land

To improve the accuracy and traceability of temperature and humidity measurements in ground level measurements

- Analysis of the siting influence on air temperature measurements in terms of uncertainty components.
- Determination of the influence of rain and snow albedo on air temperature measurements.
- To evaluate the intrinsic behaviour of thermometers and humidity sensors plus radiation shields to define calibration procedures and methods to evaluate the measurement and calibration uncertainties with the aim of improving ISO Guide 17714:2007.
- To ensure consistency and coherence of meteorological measurements carried out in different places.
- Development of procedures for traceable dynamic calibrations and uncertainty calculation of hygrometers used to measure the humidity near the Earth surface.
- Development of a humidity generator capable of fast step changes to study the response of air-humidity sensors to fast humidity changes.

- To identify the needs of traceability and uncertainty calculation of soil moisture measurements and to carry out initial experimental trials of the relevant procedures.
- Analysis of drift of weather-station hygrometers and its impact on uncertainty applicable to meteorological humidity datasets.

Results

1. <u>Air</u>

The project advanced detection techniques for the in-situ monitoring and quantification of ECVs in the upper atmosphere. Calibration facilities and procedures were developed in the relevant ranges and also for the extreme ECV values. Traceability was established and the instruments' contribution to the measurement uncertainty was evaluated, together with robust thermodynamic investigations of the thermal aspects of the measurements.

Calibration of radiosondes under atmospheric conditions. The project developed a calibration facility for water-vapour radiosondes in the 0.03 - 1.5 μmol/mol interval. The pressure and temperature lower limits used (1 kPa and -80 °C and 20 kPa and -95 °C) simulated the conditions met during the ascent in the troposphere and lower stratosphere. The mixing ratio (ratio of vapour to dry air) uncertainty was less than 2 %. This is the first example of a primary standard able to provide traceability in real upper-air conditions.

Measurement of the enhancement factor under atmospheric conditions. The water vapour enhancement factor takes into account the non-ideal gas behaviour of a water vapour–gas mixture. The project developed a humid air generator which focuses on atmospheric conditions from the troposphere to the tropopause (the interface between the troposphere and the stratosphere), i.e., a pressure range from 101325 Pa to 40000 Pa and humidity from 300 ppmv (parts per million by volume) to 1 ppmv. The handling of the mixing ratio of water in the air was based on evaporation/dilution principle.

On-site calibration of airborne instruments. A mobile, compact, and robust water vapour generator, which uses water permeation through the air-purged plastic tubing, was developed and manufactured. This can be used for the on-site calibration of airborne instruments, with a stability (key for a portable system) of 1.98 % over four months, in the 1 – 20 ppmv interval. A Selective Extractive Airborne Laser Diode Hygrometer was also developed as a "calibration-free" system, being based on absolute measurements. It is capable of relative uncertainty of 4.3 % corresponding to 3 ppmv in the range of humidity met in flight conditions.

Measurement of fast transients of temperature and humidity. A fast-responding version of a non-contact thermometer and hygrometer was constructed at NPL, for response-time testing of temperature and humidity sensors. Fully integrated signal processing enables 30 complete readings per second, including cross-variable corrections of temperature and humidity values in real time. The instrument was successfully demonstrated in the temperature range of −40 °C to +40 °C and dew point range of −43 °C to +38 °C, including comparisons of conventional (slower-responding) instruments against the device.

Development of spectroscopic techniques as standards for traceable humidity measurements and on-site references. A fast direct tuneable diode laser absorption spectrometer that combines scanning units with retro-reflective mirrors was designed and built. This covers a measurement area of 0.8 x 0.8 m^2, and achieves measurement rates of 2.5 Hz. It achieved relative uncertainty of less than 6 % of absolute concentration measurements and 1.1 ppmv m^{-1} $Hz^{-1/2}$ length and bandwidth normalised detection limit.

Development of traceable humidity sensors based on microwave resonators with low response time and small size. A prototype of a fast airborne microwave hygrometer (volume 30 cm^3), operating from –50 °C to 10 °C (frost point temperature) and from –20 °C to 20 °C (dew point temperature), was built. The measurement range was from 3 ppmv to 105 ppmv, and the uncertainty was close to 1 ppmv. A comparison with a CETIAT calibrated chilled-mirror hygrometer showed that it is suitable for use as a standard for humidity measurements.

2. <u>Sea</u>

The project developed new tools to reduce the measurement uncertainty on oceanic temperature and salinity, employed in thermodynamic models to determine the heat flux carried by seawater and the consequent effects on the climate. This work improved the quality and the traceability of deep-ocean temperature measurements and contributed to the reduction of the measurement uncertainties.

Pressure dependence of deep-sea thermometers. A facility to compare deep-sea thermometers in a high-pressure chamber was developed and is available at Royal Netherlands Institute of Sea Research (NIOZ). Pressure dependence of Sea-Bird Electronics thermistors (the biggest manufacturer and supplier of oceanographic thermometers) was measured at 500 bar (-0.30 mK / 100 bar) and confirms the values observed in the sea over the range from -0.17 to -0.33 mK / 100 bar. A 100 bar pressure corresponds to a depth of approximately 1000 meters.

Thermodynamic calibration of deep-sea thermometers. The project integrated and calibrated deep sea thermometers into a combined acoustic gas thermometer and calorimeter from -5 °C to 35 °C, with an uncertainty below 0.5 K. Previously, the best achievable calibration uncertainties on high-grade deep ocean thermometers were close to 2 mK.

Test and calibration facility for refractive-index salinometers. To make accurate, in-situ, and absolute salinity measurements, the European project NAOS (Novel Argo Ocean Observing System, a Copernicus project to consolidate and improve the French contribution to the international Argo observing system and to prepare the next scientific challenges for in-situ monitoring of the world ocean) developed an absolute salinometer based on the refractive index of seawater. The project characterised this instrument as a necessary aid to its commercial deployment.

Distributed temperature sensors based on optical fibre Bragg gratings. To improve the traceability of the sea-surface and sea-profile temperature measurements, optical fibres based on Bragg grating were designed, realised, tested, and characterised as distributed temperature sensors by CEM, CSIC and UPC. They consist of several Bragg gratings recorded along the optical fibres. These fibres were used as thermometers and were deployed in the OBSEA underwater observatory (at Vilanova i la Geltrú, Barcelona, Spain) in order to perform traceable measurements of the sea-water profile and surface temperatures. The results show that the fibre Bragg gratings are suitable to measure the sea temperature, but this first design must be improved to reduce uncertainties.

3. Land

The project provided traceable procedures for sensor calibration, sensor characterisation, and measurements of terrestrial (albedo, permafrost and soil moisture) and surface (air temperature, water vapour and precipitation) ECVs defined by GCOS, with a consistent, realistic and reliable uncertainty calculation.

Influence of siting, radiation shield, rain, and albedo on air temperature and humidity measurements. The project investigated the self-heating, hysteresis, and response time of all kinds of thermometers. The effect of the self-heating in resistance thermometers was found to be 0.04 ºC to 0.4 ºC (depending on the thermometer design and environmental conditions), for electrical currents of 1 mA and 3 mA respectively, and with the thermometer surrounded by air. The effect of hysteresis was 0.02 ºC to 0.04 ºC, depending on the thermometer design, in the temperature interval 10 – 50 ºC.

The effect of the snow albedo effect (incident sunlight reflected by the snow) on near ground air temperature measurements was investigated both theoretically and experimentally. On site experimental comparison of solar shields by parallel observations of six pairs of instruments exposed and not exposed to snow albedo showed a maximum temperature difference between couples of identical instruments of 3 °C; the uncertainty of the temperature differences, evaluated in field conditions, is 0.3 °C (k=2). The contribution of the snow albedo to the uncertainty of near ground air temperature measurements was estimated to be 1.73 °C (k=2). These results led to two improvements in ISO guides addressed to the end users and to manufacturers of atmospheric temperature sensors.

Three identical experiments were carried out over a year, in Czech Republic, Italy, and Spain, to evaluate the effect of obstacles (trees, roads, buildings) on near-surface air temperature measurements. The measurement uncertainty of the combined sensor and shield apparatus was estimated to be 0.1 °C (k=1); the instrumental drift was estimated to be 0.01 °C, over 2 years. The roads were observed to contribute to the measurement uncertainty by 1.5 °C (at 1 m distance), 1 °C (5 m distance), and 0.5 °C (50 m distance). The buildings were observed to contribute by 5 °C (1 m distance); their contribution being negligible at 50 m distance. The principal factor of influence is the solar radiation, generating a building effect up to 3 ºC on sunny days and up to 1 ºC on cloudy days. The effect of trees showed high seasonal variability, having the same amplitude as the effect of the road, but with opposite sign.

Development of a humidity generator, capable of fast steps, to study the response of air-humidity sensors to fast humidity changes. A climatic chamber reaching low temperatures (-60 °C) is operational at CETIAT. A water vapour generator capable of fast humidity steps was integrated into the chamber to study the response time of air-humidity sensors. CETIAT and PTB integrated a long path IR cell and a measuring chamber to place the highly accurate and high-speed instruments as close as possible to the device under test. The spectrometer has a maximum sampling rate of 7 ms at water vapour concentrations from 500 to 5000 ppmv. Depending on the device under test, the distance to the spectrometers laser grid is adjustable from 1 to 5 cm.

Precipitation and soil moisture. The project issued a report on the measurement methods of soil moisture and the relevant normative. A survey on the measurement and calibration needs collected more than 100 responses.

Consistency and coherence of meteorological measurements carried out in different places. The project organised an “Interlaboratory comparison of metrology laboratories in meteorological organisations”, and 18 laboratories participated. The protocol was prepared by UL, in collaboration with the WMO Regional Instrument Center region VI, and became an official WMO CIMO Procedure.

Analysis of drift of weather-station hygrometers and its impact on uncertainty applicable to meteorological humidity datasets. UK Met Office datasets of weather-station hygrometer calibrations from 2012 to 2014 were analysed to make estimates of hygrometer drift, and of its impact on bias and uncertainty of climate data. Sensors returned from use had typical drift of up to +4 % relative humidity, with high scatter (standard deviation) of up to 4 %. This shows a need for special precautions when interpreting observations and attributing uncertainty, particularly at high relative humidities.

Actual and potential impact

Dissemination

The consortium gave 85 presentations at international conferences including Arctic Circle Assembly, TEMPMEKO International Symposium on Temperature and Thermal Measurements in Industry and Science, Symposium on Thermophysical Properties, and the project’s Metrology for Meteorology and Climate conference which is now recognised worldwide.

The presentation of the project activities in WP2 from C.G Izquierdo at the IMEKO TC19 workshop on “Metrology for the sea” (October 2017) was awarded the best conference paper.

24 papers were published in peer-reviewed scientific journals such as *Meteorological Applications, Metrologia, Measurement Science and Technology* and the *International Journal of Climatology*. Articles were published in trade journals *Arctic Metrology, Tracing Glacier Retreat,* and *Metrology in high mountain environments.* In addition, articles were published in popular newspapers *La nuova provincia* (a local newspaper) and *La Stampa.*

The consortium ran 13 training courses targeted at stakeholders and environmental agencies. Topics covered were humidity measurement and calibration, the reliability of humidity and moisture measurements, metrology for meteorology and climatology, general and thermal metrology for the environment, and temperature measurement and calibration.

Early impact

The following services were developed during the project:

- World leading manufacturers are using the project calibrations and tests to improve their instruments:

INRIM and VTT characterised a reference radiosonde prototype for Vaisala (world leader in environmental and industrial measurement). These results will allow Vaisala to improve the product for humidity and temperature measurement;
The snow albedo experiment made by BEV and INRIM provided recommendations on how to improve the instruments by delivering values to quantify the effect of backward radiation on systems made by Rotronic, Barani, CAE and Lombard & Marozzini;
The study on sensor dynamics and self heating made by CMI, CEM, INRIM and SMU (REG) provided information on sensor performance to Vaisala, NKE, Rotronic and Luft.

- A facility to compare deep-sea thermometers in a high-pressure chamber was developed at the Royal Netherlands Institute of Sea Research (NIOZ). It was used to measure pressure dependence of Sea-Bird Electronics thermistors (the biggest manufacturer and supplier of oceanographic thermometers).
- NPL reduced the uncertainty of their UKAS calibration service in the meteorological temperature range -50 °C to +20 °C .
- NPL calibrated 12 specialised air-temperature sensors for aircraft use for customer Facility for Airborne Atmospheric Measurements.
- The University of Genova installed a calibration device for tipping-bucket rain gauges at Environmental Measurements Ltd (UK).
- The University of Genova developed a calibration device for tipping-bucket rain gauges at LSI Lastem srl (Italy): two prototypes have been delivered to the Hong Kong Observatory and to the EML UK company.
- INRIM calibrated sensors are used to continue recording for the historical temperature series at Regio Collegio di Moncalieri, part of the WMO recognised centennial stations.
- Staff from both INRIM and the Institute of Atmospheric Sciences and Climate (Italy) calibrated atmospheric and permafrost temperature sensors for environmental measurements in the Arctic, at the research town Ny-Ålesund.
- NPL built a fast responding version of the non-contact thermometer and hygrometer instrument (Objective 1) for response time testing of temperature and humidity sensors.

WMO CIMO (Commission for Instruments and Methods of Observation), WMO CCI (Commission for Climatology), and ISTI (International Surface Temperature Initiative) were updated on the project results during teleconferences.
Membership of the JRP coordinator in the WMO Expert Team enabled the WMO to address the project work and to uptake the results (see next section on standards).

Contribution to standards

The project consortium participated in a number of standard committee activities, and provided inputs to the following documentary standards:

- CIMO ET-A1-A2/Doc.8.1 - Guidelines on combining information from composite observing systems
- WMO 19289: Sustained Performance Classification for Surface Observing Stations on Land 1/6 24/06/2014

Potential future impact

The calibration procedures, the assessment of the measurement uncertainties, and new instrumentation for hygrometry and sea measurements are expected to have a long-term impact on the reliability of climate trend evaluations.

The numerical simulation of radiative heat transfer was used to design a chamber for calibration of air temperature sensors for the EMPIR project 15RPT03 HUMEA “Expansion of European research capabilities in humidity measurement” of the 2015 Research Potential call.

Members of the project consortium, who are now members of WMO CIMO expert teams, are promoting the following activities that follow on from the work of the project:

- A proposal is being discussed by the WMO CIMO A.3 *Expert team on Instrument intercomparisons*, about a comparison of thermometers and radiation shields as a future activity lasting 3 years: it will be submitted to the CIMO Session in October 2018 for inclusion in the future work plan (2018-2022).
- Interlaboratory comparison procedure and protocol in the field of temperature, humidity and pressure in Asia and Australia WMO regions II and V in collaboration with Region VI (Europe) (was agreed in March 2018 – Document: OBS-WIGOS/OBS- 06023/2018/OBS/OSD/RIC Inter-laboratory comparison for RICs in RA II and RA V, in collaboration with RA II&V)

List of publications

1. In situ calibration of meteorological sensor in Himalayan high mountain environment, A. Merlone, G. Roggero, G. Verza, Meteorol. Appl. **22** 847 (2015) doi: 10.1002/met.1503

2. Arctic metrology: calibration of radiosondes ground check sensors in Ny-Ålesund, C. Musacchio, S. Bellagarda, M. Maturilli, J. Graeser, V. Vitalec, A. Merlone, Meteorol. Appl. **22** (2015) 854 doi: 10.1002/met.1506

3. A combined non-contact acoustic thermometer and infrared hygrometer for atmospheric measurements., Underwood, R., Gardiner, T., Finlayson, A., Few, J., Wilkinson, J., Bell, S., Merrison, J., Iverson, J.J. and Podesta, M., Meteorol. Appl. **22** (2015) 830 doi: 10.1002/met.1513

4. A calibration facility for automatic weather stations, G. Lopardo G, Bellagarda, S, Bertiglia, F, Merlone, A, Roggero, G, Jandric, N, Meteorol. Appl. **22** (2015) 842 doi: 10.1002/met.1514

5. The MeteoMet project – metrology for meteorology: challenges and results, A. Merlone *et al*., Meteorol. Appl. **22** 820 (2015) doi: 10.1002/met.1528

6. Metrological analysis of a gravimetric calibration system for tipping-bucket rain gauges, Santana, M. A., Guimarães, P. L., Lanza, L. G. and Vuerich E., Meteorol. Appl. **22** (2015) 879 doi: 10.1002/met.1540

7. The Metrology for Meteorology Conference: MMC 2014, A. Merlone, C. Musacchio, F. Sanna, Meteorol. Appl. **22** 817 (2015) doi: 10.1002/met.1548

8. Validation of a calibration set-up for radiosondes to fulfil GRUAN requirements, H. Sairanen, M. Heinonen, R. Högström, Meas. Sci. Technol. **26** (2015) 105901 doi: 10.1088/0957-0233/26/10/105901

9. Metrological challenges for measurements of key climatological observables: oceanic salinity and pH, and atmospheric humidity. Part 1: overview Feistel, R et al. Metrologia 53 (2016) R1 doi: 10.1088/0026-1394/53/1/R1

10. Metrological challenges for measurements of key climatological observables. Part 4: atmospheric relative humidity, JW Lovell-Smith, *et al*., Metrologia 2016 **53** R40, doi: 10.1088/0026-1394/53/1/R40

11. Effect of changes in temperature scales on historical temperature data, Pavlasek, P., Merlone, A., Musacchio, C., Bergerud, R.A., Knazovicka, L., International Journal of Climatology **36** 2016 1005 doi: 10.1002/joc.4404

12. Towards a calibration laboratory in Ny-Ålesund, Chiara Musacchio, Andrea Merlone, Angelo Viola, Vito Vitale, Marion Maturilli, Rend. Fis. Acc. Lincei **27** (2016) 243 doi: 10.1007/s12210-016-0531-9

13. Reassessing changes in diurnal temperature range: A new dataset and characterization of data biases, P. W. Thorne, *et al*., Res. Atmos. **121** (2016) 5115 doi: 10.1002/2015JD024583

14. A methodology for study of in-service drift of meteorological humidity sensors, S Bell, P Carroll, S Beardmore, N Mander, C England, Metrologia (2017) **54** S63 doi: 10.1088/1681-7575/aa6dd0

15. Characterisation of the humidity calibration chamber by simulations, J. Salminen, H. Sairanen, P.Grahn, R.Högström, A.Lakka, M.Heinonen, Int J Thermophys (2017) **38** 84 doi: 10.1007/s10765-017-2221-y

16. Vineyard diseases detection: a case study on the influence of weather instruments calibration and positioning, F. Sanna, A. Calvo, R. Deboli, A. Merlone, Meteorological Applications 2017 early view article doi: 10.1002/met.1685

17. An improved non-contact thermometer and hygrometer with rapid response Underwood, R., et al. Metrologia **54** (2017) S9 doi: 10.1088/1681-7575/aa54c6

18. The MeteoMet2 Project – Highlights and Results, A. Merlone, F. Sanna, S. Bell, et al. Meas Sci Technol (2017) doi: 10.1088/1361-6501/aa99fc

19. Effect of Pressure on Deep-Ocean Thermometers, A. Peruzzi, R. Bosma, S. Ober, C. Bruin-Barenregt, R. van Breugel Int J Thermophys (2017) 38:163, DOI: 10.1007/s10765-017-2297-4

20. Albert Garcia-Benadí, Joaquin del Rio Fernandez, Marc Nogueras-Cervera, C. García Izquierdo, D. del Campo, S. Hernandez Albert Garcia-Benadí, Joaquin del Rio Fernandez, Marc Nogueras-Cervera, C. García Izquierdo, D. del Campo, S. Hernandez, Instrumentation Viewpoint ISSN 1886-4864,(2016) B-32814-2006 http://hdl.handle.net/2117/99915

Submitted

21. Low pressure and temperature dew/frost-point generator, H. Sairanen, M. Heinonen, R. Högström, J. Salminen, S. Saxholm, H. Kajastie Int J Thermophysics

22. Evaluation of uncertainties in surface air temperature measurements due to road siting with respect to the WMO classification, Coppa G., Merlone A., Quarello A., Franco-Villoria, Ignaccolo Meteorological Applications

23. Development of a low-frost point generator operating at sub-atmospheric pressure, R Cuccaro, L Rosso, D Smorgon, G Beltramino, S Tabandeh and V Fernicola Measurement Science and Technology

24. Evaluation of the self-heating effect in a group of thermometers used in meteorological and climate applications C. García Izquierdo *et al.* METEOROLOGICAL APPLICATIONS

JRP start date and duration:	1 October 2014, 36 months
JRP-Coordinator: Dr Andrea Merlone, INRIM, Tel: ++39 011 3919 734 E-mail: a.merlone@inrim.it JRP website address: http://www.meteomet.org	
JRP-Partners: JRP-Partner 1: INRIM, Italy JRP-Partner 2: BEV-PTP, Austria JRP-Partner 3: CEM, Spain JRP-Partner 4: CETIAT, France JRP-Partner 5: CMI, Czech Republic JRP-Partner 6: CNAM, France JRP-Partner 7: CSIC, Spain JRP-Partner 8: DTI, Denmark JRP-Partner 9: IMBiH, Bosnia and Herzegovina	JRP-Partner 10: VTT, Finland JRP-Partner 11: NPL, United Kingdom JRP-Partner 12: PTB, Germany JRP-Partner 13: SMD, Belgium JRP-Partner 14: TUBITAK, Turkey JRP-Partner 15: UL, Slovenia JRP-Partner 16: VSL, Netherlands JRP-Partner 17: SHOM, France
REG-Researcher 1 (Associated Home Organisation):	Joaquín del Río Fernández UPC, Spain
REG-Researcher 2 (associated Home Organisation):	Antonio Castrillo SUN, Italy
REG-Researcher 3 (Associated Home Organisation):	Luca Lanza UNIGE, Italy
RMG1 Researcher (Associated Employing Organisation):	Danijel Sestan FSB, Croatia
RMG2 Researcher (Associated Employing Organisation):	Aleksandra Kowal INTiBS, Poland
RMG3 Researcher (Associated Employing Organisation):	Peter Pavlasek SMU, Slovakia
RMG4 Researcher (Associated Employing Organisation):	Tanja Vukicevic MER, Montenegro

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union