FINAL PUBLISHABLE REPORT

Grant Agreement number 19SIP03

Project short name CRS

Project full title Climate Reference Station

Project start date and duration:	1 November 2020, 36 months	
Coordinator: Andrea Merlone, INRIM Tel: +39 01 13 91 97 34 E-mail: a.merlone@inrim.it Project website address: https://www.meteomet.org/crs/		
Primary Supporter: Manola Brunet, World Meteorological Organisation		
Internal Funded Partners: 1. INRIM, Italy 2. DTI, Denmark 3. SMU, Slovakia	External Funded Partners:	Unfunded Partners:

TABLE OF CONTENTS

1 Overview

To understand climate change, scientists need detailed data on many different environmental parameters. Data on temperature, humidity and pressure – currently captured by automatic weather stations for forecasting – could provide important additional data for climate monitoring. But to use this data reliably, climate scientists need to compare data from different instrumentation using different measurement methods and operated by different network stations. A consistent approach to instrument calibration with robust links to SI units and a better understanding of the environmental factors that influence measurement accuracy are key for introducing a reference system that will underpin all climate measurements. This project built on the metrology for meteorology results and methods developed during the preceding EMRP projects ENV58 MeteoMet2 and ENV07 MeteoMet and has provided definitions, guidelines and measurement methods to improve the comparability of climate data. This is a key goal of the project's primary supporter, the World Meteorological Organisation (WMO) which needs consistent technical specifications for the set-up of Climate Reference Stations to increase data comparability between climate observing networks.

2 Need

Continuous, high-quality, scientific observations of the global environment are critical for defining the state of the Earth's integrated environmental system and establishing climate trends. The Intergovernmental Panel on Climate Change (IPCC), the World Meteorological Organisation and the United Nations Environment Program and Framework Convention on Climate Change (UNFCC) have recognised the need for sustained and robust climate observations. It has also become increasingly evident that data gathered for routine weather predictions do not always meet the quality standards needed for climate science purposes. Small changes over long time periods are characteristic of climate trends, but these occur during larger shorter-term variations associated with weather and other natural climate variations. Measurements also need to be comparable over large geographic areas and extended time frames through the traceability to a metrological reference. The introduction of climate reference instruments at existing meteorological network stations would provide high accuracy quality data and enable the identification of potential problems with network data homogeneity. A tiered station concept is included in the WMO observing network design principles and GCOS (Global Climate Observing System) report 226, which promotes the transferral of information from high quality reference observations to other measurements to improve their quality and utility.

At present a lack of unique definitions of the key instrumental and technical features for a climate reference station, as well as reference measurement procedures has generated a multitude of approaches among different nations and National Meteorological and Hydrological Services (NMHS), reducing the comparability of results over geographic areas and across time periods. This is the main cause of the huge efforts needed to harmonise climate data and detect biases in local and global climate trends.

ENV58 MeteoMet2 and its predecessor project ENV07 MeteoMet analysed the performance of meteorological instruments, improved SI traceability and investigated how quantities of influence such as temperature, humidity and snow cover effect affect instrument responses. Key outputs from these projects were: (a) dedicated calibration procedures and specific system characterisations for the realistic calibration of sensors used for climate related measurements in the field and (b) an evaluation of the effects of weather conditions and siting of the CRS on measurement quality. These outputs generate a recognised contribution to the WMO "Guide to Instruments and Methods of Observation" (WMO-No. 8), which is the world reference document on implementing observing stations.

This project directly built on ENV58 MeteoMet2 outcomes and has characterised temperature sensor features and reference station set-ups both in the lab and during field trials. From the results, this project prepared and submitted recommendations to the WMO and the GCOS Surface Reference Network (GSRN) for their implementation. These have contributed to the definition of characteristics and requirements for instruments and sensors of candidate stations for the GSRN (activity of the Sub Group 5 "Uncertainty" of the GCOS Task Team on GSRN). The produced recommendations and journal papers will also be included in the literature forming the basis of the work of the WMO (Commission of infrastructure Standing Committee Measurement Instrumentation and Traceability) INFCOM SC-MINT Expert team on Measurement Uncertainty (ET-MU) for the revision of ANNEX 1A to the WMO Guide No.8 and for the Measurement Quality Classification Scheme.

3 Objectives

The goal of this project has been to create impact by supporting the WMO and the GCOS in defining the measurement parameters, and the requirements needed for a technical specification for reference stations in ground-based climate observation networks.

The specific objectives were:

1. To define and evaluate the characteristics of reference grade temperature instruments for climatology use, by the identification of uncertainty budget components, including time-series adjustment estimations to preserve their homogeneity, and setting target measurement uncertainties. This includes the commissioning of a reference grade observing station in the lab, for performance assessment.
2. To install the laboratory evaluated reference grade observing station (objective 1) in an appropriately identified field site and operate it for at least one year to enable instrument performance to be assessed and measurement uncertainties determined over a wide range of environmental seasonal conditions. Combined with the results of objective 1 this will form the basis of a paper to be submitted to an open access meteorological journal.
3. To draft and submit a report containing comprehensive recommendations for potential inclusion in documents of (a) the WMO Commission of Instruments and Methods of Observation task team on “Uncertainty” and task team “Classification (WMO guide No. 8), (b) the WMO Commission of Climatology requirements for the recognition of reference stations and c) the GCOS manual for the Global Surface Reference Network based on the results from objectives 1 and 2.

4 Results

Objective 1: To define and evaluate the characteristics of reference grade temperature instruments for climatology use including the commissioning of a reference grade observing station in the lab, for performance assessment.

The results of the project’s survey of commercially available thermometers and shields, both new technologies and those normally adopted by ground based meteorological stations, has led to the selection of devices for performance evaluation in a laboratory setting and the derivation of their associated measurement uncertainties under controlled conditions. Results from these evaluations have been included in recommendations for submission to the WMO, and GCOS for the commissioning and operation of climate reference stations (objective 3).

A project achievement regarded the selection of three thermometers and solar shields, commercially available and received from previous collaborators of the parent MeteoMet and MeteoMet2 projects, equipped with high quality meteorological PT100 thermometers. This group of instruments, and potentially, others received from different manufacturers were characterised in the laboratory to evaluate the effect of rain, self-heating, hysteresis, calibration, prior to their installation in the field.

In total four different PRT sensors from multiple manufacturers (Vaisala, Rotronic, Marozzini and Cal Power) were tested for their metrological performance in terms of stability, hysteresis and self-heating. These tests were done for temperature ranges typical for air temperature measurements for climate which are from -40 °C up to +60 °C.

Results of sensor stability expressed by the standard deviation over a time period of 5 h (when the climatic chamber temperature was considered stable) have shown the lowest stability of 0,021 °C at 20 °C. Furthermore, the lowest stability of sensor output was visible for all sensors at -40 °C (maximum of 0,018 °C) and at 20 °C (maximum of 0,021 °C).

The hysteresis effect measurements followed, in order to numerically evaluate the temperature differences at the same temperature values when reached by cooling or heating. It is furthermore important to point out that the values used to express these differences were also calculated as a difference from the reference thermometer temperature in each temperature point. The results have shown that the highest hysteresis effect was found to be 0,05 °C measured at 0 °C. For all of the sensors the highest levels of hysteresis were found at around -40 °C peaking at 0,04 °C. Other differences were found to be negligible.

The self-heating of tested sensors exhibits multiple dependencies of the level of supply current that vary with tested sensor and temperature point. Therefore, a clear unified conclusion in this matter cannot be made at the moment.

Combination of four different shields and the four selected thermometers were tested to evaluate the characteristics of each individual combination.

Tests for evaluating the bias on temperature measurements due to precipitation followed. During the study, the thermometer was positioned in the shield, and the shield was exposed to heavy rain with a temperature of around 11 °C ± 0.5 °C. The air temperature in the room was 23 °C ± 3 °C.

The test showed no significant difference between the thermometers. There were significant and systematic differences between actively aspirated and naturally ventilated shields. Actively aspirated shields showed a drop in recorded temperature of less than 1 °C, at steady state rain, while the naturally ventilated shields would record temperatures up to 4 °C lower during steady state rain, while the room temperature was kept constant.

Similarly, the recovery time after the rain had stopped was significantly longer on naturally ventilated shields than actively aspirated shields. The naturally ventilated shields showed recovery times between 2 – 5 hours, while actively aspirated shields all had recovery times of less than 1 hour before the recorded temperature had returned to ambient room temperature.

The test did however not consider any natural convection which is likely to appear in nature, and which would probably reduce the effects of the rain on naturally ventilated shields.

In conclusion, this part of the work gave relevant information for the selection of best available combinations of thermometers and solar shields for generating reference-grade measurements of near surface atmospheric air temperature. Results showed that smaller thermometers in artificially aspirated shields performed better, in terms of protection against solar radiation bias, followed by same smaller thermometers in helical naturally ventilated shields. No studies are available in literature on the effect of the rain on air temperature accuracy and this work perfectly follows the results of the parent MeteoMet2 JRP, where preliminary investigations of this effect were evaluated. Besides the completion of the objective for this project, the overall result of this investigation highlighted the need to further study and evaluate the rain overcooling bias on different kind of solar shields and the time required to recover correct, accurate temperature values.

Objective 2: To install the laboratory evaluated reference grade observing station in an appropriately identified field site and operate it for at least one year to enable instrument performance to be assessed and measurement uncertainties to be determined

The performance validation and associated measurement uncertainties determined during field operation of selected instrumentation (objective 1) has driven the realisation of a reference station prototype set-up. The prototype's performance has been evaluated and included in recommendations for submission to the WMO, and GCOS for the commissioning and operation of climate reference stations (objective 3).

The site

To optimize the performances of a climate reference station, the site is a fundamental contribution in minimizing representativeness uncertainties and errors in the measurement results due to obstacles in the vicinity of the instrumentations. Reference stations should be positioned in a place where land cover, vegetation and soil characteristics are as uniform as possible, and representative of the conditions of the surrounding area.

An optimal site for hosting a climate reference station is a location whose physical characteristics do not introduce biases in the measurement results. The biases due to the site mainly affect the measurand, reducing its representativeness with respect to the climate of the area.

WMO (2018) identifies some of the sources of error due to the site features and proposes a classification scheme. Prescriptions are given to reduce the effect of the site on temperature, humidity, wind (speed and direction), solar radiation and precipitation. Each site will need to be large enough to house all instrumentation without adjacent instrumentation interfering with one another, with no shading or wind-blocking vegetation or localized topography, and at least 100 m from any artificial heat sources.

Such prescriptions should be adopted also for identifying sites for hosting a new climate reference station.

- Obstacles such as roads, buildings, trees and water sources should be at more than 100 m of distance from the measuring installation);

- The site should be flat at least on a radius of more than 100 m around the measuring point;
- No shadows should be projected during the whole daytime on the measuring point, including natural shadowing from hills or mountain peaks;
- Obstacles from far should have a very small angular projection on the measuring site
- The 100 m distance is based on a precautionary evaluation to avoid the effect of obstacles.

Ahead of the planned time schedule, a field site in Italy in a public park ruled by “Ente di gestione delle aree protette dei Parchi Reali” and “Città di Nichelino” near Torino (45°00'21.1"N, 7°36'37.5"E) with characteristics aligned with the WMO recommendations has been identified: a formal agreement with the public owner of the site, INRiM and Società Meteorologica Italiana has been signed in summer 2022, to allow deployment of selected instruments, experimental activities to start and future data management.

Based on the considerations above, a site has been selected, also taking into account further specific requirements for this project

the vicinity to INRiM (to speed up travel to the site, reduce carbon impact and person time)

a public area (to avoid possible changes in the use of the terrain with new buildings or similar)

a flat surface with more than 100 m of radius

the availability of the area owner to cut the trees in the whole radius of 100 m around the installation

the possibility to sign a formal agreement for the use of the land (limited to the small portion occupied by the station)

Safety and security aspects (protection against vandalism)

The site identified is located in the “Park of Stupinigi”, a public area at 3 km from INRiM, in the municipality of Nichelino. The coordinates of the site are :

45°00’21’’N

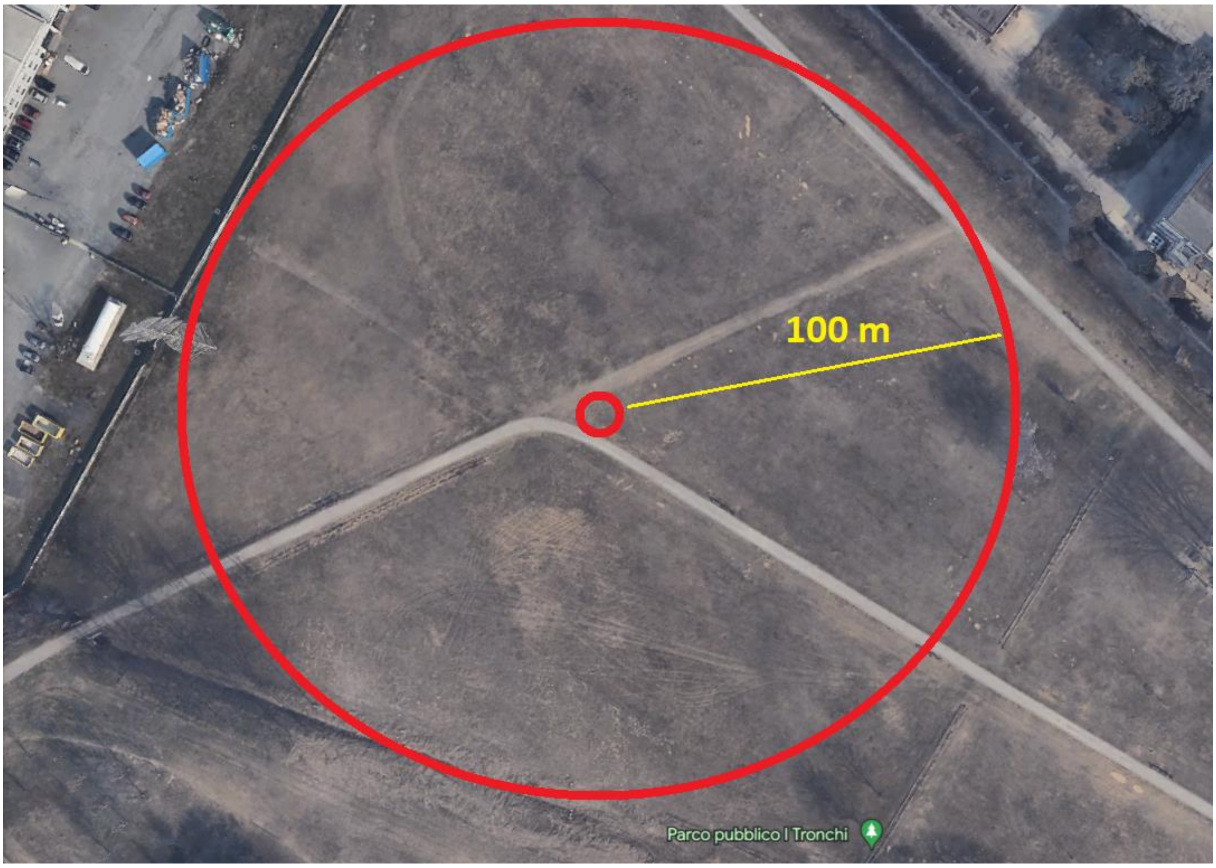
7°36’37’’ E

Soil cover: natural grass

Siting class: 1

No obstacles within a radius of 100 m

Koppen climate zone: Cfa



Google Earth picture of the site, with the 100 m radius free of obstacles around the station, positioned in the center of the red circle. It is worth to mention that all trees have been cut in the area internal to the red circle, according the WMO prescriptions, in order to reduce uncertainties in the data representativeness and measurement errors.

The site selected has been officially made available to INRiM, through a contract signed with the owner and the required documentation submitted to the local authority. The area has been protected by appropriate fences (made to minimise the impact to the instrumentation to be installed). All technical preparatory work has been concluded, such as the concrete bases for the instruments, poles and cabling. In late summer 2023 the station was finally installed.

Picture of the site during the positioning of the fence limiting the instrumental area.

Reference Station Installation

Permissions for the installation of the station have been approved by the technical office that manages the site. A further framework agreement has been signed between INRiM and the local authority (Comune di Nichelino) for increasing the collaboration also in view of disseminating the information on the unique climate reference created by this project, to the public and to schools.

Following the results of objective 1, sensors were selected and acquired for installation in the station, the procedure for monitoring the selected instrumentation has been designed. Data logging and specific installation structures have been designed and realised. In particular, a special setup for a selected datalogger has been programmed, in order to align the reading frequency and raw data recording, to the planned requirements for future climate reference stations within the GCOS Surface Reference Network.

Following the requirements in terms of data quality, primary measurements (at reference level) and need to measure the so-called "Associated Quantities of Influence" (AQI), the configuration of the INRiM Climate Reference Station is now the following:

Variable	Instrument	Calibration uncertainty
Temperature (reference)	PRT 100 (4 wire connection)	0.012 °C
Temperature – humidity (AQI)	Vaisala HMP 155	0.05 °C 3 % RH
Precipitation	SIAP TP200	Total: 2%-10% Intensity: 2%
Pressure	Paroscientific DIGIQUARTZ	10 Pa
Wind speed and direction (reference)	GILL HS50 3 Axis ultrasonic anemometer	Speed: < 1 m/s Direction: <1°
Wind speed and direction (AQI)	Gill Windsonic	2%
Solar radiation (direct and reflected)	2 Hukseflux LP02 05 Second class pyranometers	<1.8 %

This objective was fully achieved and completed, although the station was not operated for a full year during the lifetime of the project, due to difficulties in finding an appropriate location and for preparing and signing all required documents and defining bureaucratic aspects. On September 28 the station was inaugurated during the “Metrology for Meteorology and Climate” International conference, held in the castle of Stupinigi, which annexed public park includes the site of station. Besides the more than 100 participants at the MMC, the event attracted the public, students and journalist, with a formal “ribbon cut” by the city Mayor. The station is now operative and data is transmitted and recorded at 10 s intervals, for being managed by “Società Meteorologica Italiana”, a highly recognised climatological Institution and group in Italy. The station will continue recording and transmitting data beyond the project lifetime, thus well recovering the missing time period and it will be included in the proposed WMO Measurement Lead Center

Pictures of the INRiM CRS and each instrument composing it, follow.

Picture of the Climate Reference Station

Temperature 1 (Artificially aspirated shield – PT 100)
Note1. It will be moved 4 m from the main pole to avoid possible influences
Note 2. A third thermometer will be added to increase redundancy in temperature data

Temperature 2 (Naturally ventilated shield – thermohygrometer)

Direct and reflected radiation (2 Huseflux pyranometers)

Pressure (ParoscientificDIGIQUARTZ)
Logger and transmitter (SIAP logger and GSM transmitter)

Wind Reference @10 m (GILL HS50 3 Axis)
Wind AQI (Gill Windsonic)
Note. in picture the AQI anemometer is under comparison against the reference and it will be moved @ 2m as prescribed

Precipitation (SIAP TP200)
Note. A larger rain gauge or anon contact one will be added, to increase redundancy

19SIP03 Climate Reference Station official start-up. The project coordinator turning on the data acquisition at the presence of the city Major (left) and president of the Italian Meteorological Society). Several press releases and TV broadcast followed.

Objective 3: Based on the results from Objectives 1 and 2, to draft and submit a report containing comprehensive recommendations for potential inclusion in documents of (a) the WMO Commission of Instruments and Methods of Observation task team on "Uncertainty" and task team "Classification (WMO guide No. 8), (b) the WMO Commission of Climatology requirements for the recognition of reference stations and c) the GCOS manual for the Global Surface Reference Network.

The results from the evaluation of selected instruments both under controlled laboratory conditions (objective 1) and also from the project's field trial (objective 2) were used to draft an advisory report on the required instrument technical features and reference station set-ups for use by surface-based climate observing networks. The document was submitted to both the WMO, and GCOS expert teams for consideration for inclusion in their guides and requirements for the setting up and operation of climate reference stations. In addition, these recommendations were also submitted to the Copernicus Climate Change Service (C3S) as a basis for consideration for the formation of an EU reference climate network and to the WMO Secretariat of the Standing Committee Measurement Instrumentation and Traceability (SC-MINT). A series of presentations to the committees on the project advances have been made by the project coordinator, in his role of chairperson or member of expert teams, time by time, during the project lifetime.

With respect to the prescriptions of GCOS 226 it was observed that more interactions among main observed variables and associated quantities of influence should be considered. In particular, the rain temperature should also be measured in order to better understand the errors due to overcooling on temperature (and humidity) measurements, and associated recovery time to reach again accurate data. (time due to the evaporation of water from solar shields and sensors). It is therefore suggested to add the interactions marked in red to the table of the GCOS 226 and GSRN.

Air temperature was also observed to cause influence on accuracy of precipitation data (to be evaluated with appropriate studies), due to changes in the evaporation of a water layer on the collector surface. This phenomenon is not present in non-catching rain gauges.

Finally, soil moisture does not seem to affect the accuracy of the measurements of air humidity, since it affects the measurand itself, thus not the accuracy (and uncertainty) of the humidity sensor's response. Primary measurements (first column) requiring other measurements to detect the respective influencing factor. GCOS 226.

	Air Temperature	Relative Humidity	Solar radiation	Wind speed & direction	Air pressure	Precipitation	Soil temperature	Soil moisture
Air Temperature		X	X	X		X X rain temperature	X	
Relative Humidity	X		X		X	X X rain temperature		X
Solar radiation	X	X				X		
Wind speed & direction	X					X		
Air pressure	X			X				
Precipitation	X			X				
Soil temperature	X	X				X		
Soil moisture	X	X				X		

This last objective was successfully completed, with submission, presentation and discussion of the findings to and with the relevant expert teams of the WMO and the GCOS. In conclusion this project delivered all the expected results and produced advanced knowledge on measurement processes and uncertainty evaluation for climate reference stations. The documents generated formed recommendations and prescriptions for the GCS Surface Reference Network, while the experimental installation will further contribute to research activities to improve measurement techniques in climatology.

Key Output and Conclusions:

The main results and output of this project are fully aligned with its scope to support further impact of previous MeteoMet JRPs. The MeteoMet projects (MeteoMet1 and MeteoMet2) significantly contributed in delivering results of direct interest for the meteorology and climatology communities and enforcing the mutual interaction and collaboration also worldwide. This SIP succeeded in both aspects by

a) Contributing in increasing an efficient collaboration between staff of participating NMIs and the WMO and GCOS experts, on the matter of technical and instrumental aspects of Climatological Reference Stations and measurement methods

b) Making available a prototype of Climatological Reference Station, installed and now fully operating in the field, with the opportunity to host studies and experiments on improving knowledge on measurement uncertainties for key Essential Climate Variables. This installation is also part of an initiative to candidate to become a WMO Measurement Lead Centre a metrology infrastructure, composed of this station and associated laboratories for the characterisation and calibration of instruments used in meteorology.

It is therefore expected that based on the established cooperation (a) and instrumental infrastructure (b) this project will generate significant impact and outreach way beyond its conclusion.

5 Impact

Early outreach and uptake

This project has promoted the widest possible uptake of the outputs of ENV07 MeteoMet and ENV58 MeteoMet2 by the WMO and the GCOS, by direct interactions between project partners who also sit on the WMO expert teams. In addition it has held and participated in a raft of public engagement activities reaching an estimated audience of hundreds of thousands via a media campaign that used TV/radio clips, and articles in the popular press. Engagement via a series of presentations to the key expert committees in this area on the project advances have been made by the project coordinator, in his role of chairperson or member of expert teams, throughout the project lifetime: the project has made a presentation on project activities to the WMO GCOS - GSRN Task Team and participated in a WMO SC-MINT meeting. Two conference presentation have been made at WAITING FOR MMC 2021 (Slovenia), an invited oral presentation at Measurements for Climate Action (UK), three presentations at the 2022 WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation (TECO-2022), one presentation at the 5th International Arctic Metrology Workshop, one at the 2022 Polar Night Week conference and one at the joint JCGM WG1 & WMO ET-MU Workshop on Measurement uncertainty in meteorology and climatology. Al presentation was presented at the international conference ITS-10 (International Temperature Symposium) with the focus on Metrological characterisation of climate reference station thermometers which is connected to the objective 1 of the project. Two presentation and the official inauguration of the station were presented at the “Metrology for Meteorology and climate” Conference, on 25-28 September 2023.

The main interaction was with the WMO GCOS Task Team on Surface Reference Network (TT-GSRN), where performances of instrumentation to complete a climate reference station were discussed, to define high quality requirements. The project coordinator presented the project advances at the several meetings of the TT-GSRN, starting in Dublin on June 2022 (in person), during the online meetings organised after and at the GSRN launch meeting in person in Torino, September 2023. Overall measurement uncertainties are studied by the GSRN task team, and it is also expected that this project delivered information of interest also in terms of impact and outreach beyond the project lifetime. Another Expert team potentially interested in this SIP results is the sub-group 5 of the TT-GSRN, tasked to define requirements for a Climate Reference Station (CRS), to be adopted in WMO documents such as the WMO 1238 on data quality for climate and in “Requirements for Climate Reference Stations” or in the “GSRN Manual”. A further WMO Expert Team is tasked to discuss and propose prescriptions for Climate Reference Stations: The Expert Team on Measurement Uncertainty of the SC-MINT (Standing Committee on Measurement, Instrumentation and Traceability). This ET-MU is requested to harmonise prescriptions on uncertainties among the different WMO publications and the figures eventually produced by this project, related to instrument performances and achievable uncertainties will be presented to this ET by the SIP coordinator. This facilitated project result dissemination, directly to the relevant expert teams for inclusion in guidance material such as the WMO “Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8) - the reference document on instrument implementation for meteorological and climatological sites. As a relevant first step in this dissemination process, at the plenary meeting of the WMO Commission for Observation, Infrastructure and Information Systems (INFCOM) the document “INFCOM-2/Doc. 6.1(6) - PROCESS TO NOMINATE AND IMPLEMENT A PILOT GCOS SURFACE REFERENCE NETWORK (GSRN)” was approved. The GSRN network requires the metrological qualification of a broad suite of instrumentation, which is partially addressed by the results of this project.

Workshop

During the “Metrology for Meteorology and Climate – MMC2023” International conference, a session on “Climate Reference Station” was organised by this project. It was scheduled as the first opening session of the MMC2023 event, as a plenary session, having the opportunity to include talks and discussions from members of the WMO GCOS Surface Reference Network, having joined the event also for formal meeting of the pilot phase of the Surface Reference Network – GSRN. Thea was the most relevant opportunity to present the project advances and the installed reference station to the key Institution involved in definition and requirements for climate observations.

Training

Project partners have also provided training to the WMO (primary supporter) staff of Regional Instrument Centres on Quality, Traceability and Compliance – General Metrology and Temperature and a training course on Traceability, Uncertainty and reference data for environmental observations to research and technical staff of NOI-PARK, a public-private consortium operating in North of Italy on environmental activities. In addition, partners exhibited at to members of the public to increase awareness of civil society about challenges of metrology in support of climatology.

Impact beyond the project lifetime

Considering the overall project results for the characterisation and tests of sensors, identification of instrumentation, the coordinator of this SIP proposed to the GSRN TT the inclusion of a research infrastructure in the “governance” document of the GSRN (Draft November 2022), approved. It is therefore under consideration that the future climate reference station installed by this SIP, together with associated capabilities and INRiM laboratories will be candidate to contribute as research facility to the GSRN. The National WMO Permanent Representative was informed of this opportunity. This is a further outreach of the project: in November 2023 INRiM formally submitted the application to become a WMO Measurement Lead centre on reference measurements and field trials. The proposal was approved by the Italian Permanent Representative and submitted to the WMO INFCOM.

Project results have also been delivered to the C3S of the European Centre for Medium-Range Weather Forecast (ECMWF) by the project coordinator who is member of the advisory board of a C3S project on uncertainty in climate data for possible future initiatives towards the creation of an EU reference climate network.

Further Outreach beyond the project lifetime.

This project’s results on the technical specifications for reference stations and sites it is expected to be of interest to instrument manufacturers to test and validate new measurement systems that may be used more broadly. The process works both ways: technological advances, new measuring principles, new solutions to reduce the effects of the influencing quantities, evolving measurement and calibration procedures, should be immediately recognised and integrated to improve the climate reference stations and networks.

The adoption of this project’s unique definition and requirements for the technical setup, measurement procedures and uncertainty evaluation for climate reference stations will substantially address the present lack of a common approach in detecting climate trends. This will improve data comparability across regions and time and allow a more robust understanding of climate evolution locally and globally. The key impact of the definition of Climate Reference Station features and implementation of the GSRN will be the capability to provide the highest quality data from meteorological and climatological observations. Apart from the obvious benefits to society of better understanding climate evolution and progress toward climate change mitigation, the availability of traceable and comparable data from a range of both critical and representative global environments will be invaluable in supporting high-quality research on climate processes and in the development and validation of new climate models.

6 List of publications

Andrea Merlone, Luigi Pasotti, Chiara Musacchio, Pierre Bessemoulin, Manola Brunet, Khalid El Faldi, Phil Jones, Gerard Van Der Schrier, Adrian Raspanti, Blair Trewin, Dan Krahenbuhl, Randy Cerveny, *"Evaluation of the Highest Temperature WMO Region VI Europe (continental): 48.8 °C, Siracusa Sicilia, Italy on 11 August 2021,* International Journal of Climatology https://doi.org/10.5281/zenodo.10491913

This list is also available here: https://www.euramet.org/repository/research-publications-repository-link/

7 Contact details

Project Coordinator: Andrea Merlone (INRIM), Tel: +390113919734, e-mail: a.merlone@inrim.it