GRUAN interactions with METEOMET

Metrology for Meteorology

Graziano Coppa

Istituto Nazionale di Ricerca Metrologica (INRiM)

g.coppa@inrim.it

On behalf of coordinator Andrea Merlone and the MeteoMet consortium

From EURAMET SRA

Metrology has a critical role to play in

- **Monitoring, understanding and predicting climate change**

- **Enabling the enforcement of EU policies in environment**

MRA

Michel Jarraud, Secretary General of the WMO, signed the Arrangement on behalf of the WMO. The signing ceremony took place on *1 April 2010*

Left to right: Len Barrie (WMO), Andrew Wallard (Director BIPM), Michel Jarraud (Secretary General WMO), Ernst Göbel (President CIPM), Wenjie Zhang (WMO)

Metrology for Meteorology.

Why?

Contribution in evaluating measurement uncertainties (Full documented traceability)

Dedicated calibration procedures (Definition of reference grade data)

25th Meeting of the
CCT • 51

RECOMMENDATION T 3 (2010)
On climate and meteorological observations measurements

The Consultative Committee for Thermometry (CCT),

considering that

- global average temperature records are essential in understanding how the climate is changing;
- the consequences of these changes have deep impacts on different aspects of social, political and economic life;
- the need exists to improve the quality of data collection by assuring worldwide traceability

- the signing of the MRA by WMO will lead to closer liaison and cooperation with the thermal metrology community;

- research and coordinated analysis is required to build up a worldwide network supplying traceable baseline data sets, needed to develop more accurate models for climate change;

recommends

- to encourage NMIs and the scientific community, especially temperature metrologists, to be prepared to face new perspectives, needs, projects and activities related to the traceability, quality assurance, calibration procedures and definitions for those quantities involved in the climate studies and meteorological observations;

- quality assurance needs of the climate change and monitoring communities.

- to support a strong cooperation between NMIs and Meteorological Institutions at local, national and international levels;

- to encourage NMIs to work with the relevant meteorological networks to support a monitoring framework for traceable climate data over long temporal terms and wide spatial scales based on best practice metrology;

Interaction with global networks

European NMIs have become members of institutions and committees dealing with environmental issues, e.g. WMO commissions, GAW, ISTI, **GCOS GRUAN**, BSRN, IRS, GEO and CEOS. Conversely, experts in meteorology and climatology now participate in working groups and task groups of CIPM's CCs and EURAMET.

Climate change and adaptation

Examples of multi-disciplinary and inter-disciplinary approach needed.

- ❑ Metrology to establish and underpin traceability of key ECVs related to **land processes**, vegetation and the carbon cycle are in urgent demand

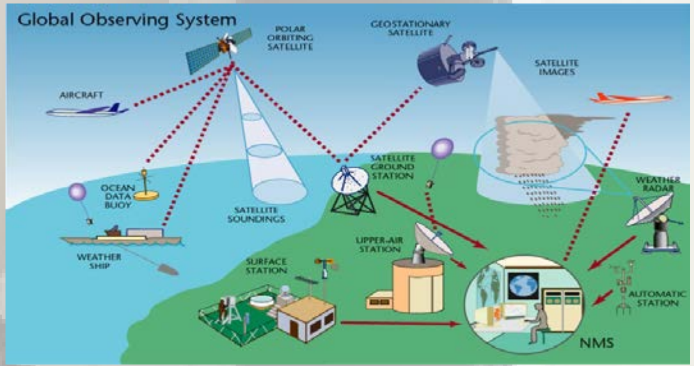
- ❑ Improved earth observation for climate monitoring using remote sensing techniques is becoming increasingly common and important and includes the **traceable linkage between space based and surface based** remote sensing **measurements**

- ❑ **Atmospheric upper air measurements (i.e. GCOS - GRUAN), ocean science**

- ❑ Climate trends in **key environmental areas**, like **arctic and alpine regions** are significantly amplified : accurate measurements to quickly capture trends are there of unique importance at a global scale […] and require self-validating in situ measurements and calibration devices operating in **arctic-based research stations**

- ❑ Small to medium scale of **network of reference stations**, purposely installed **for climatology** are missing and required for the future work of harmonisation and homogenisation

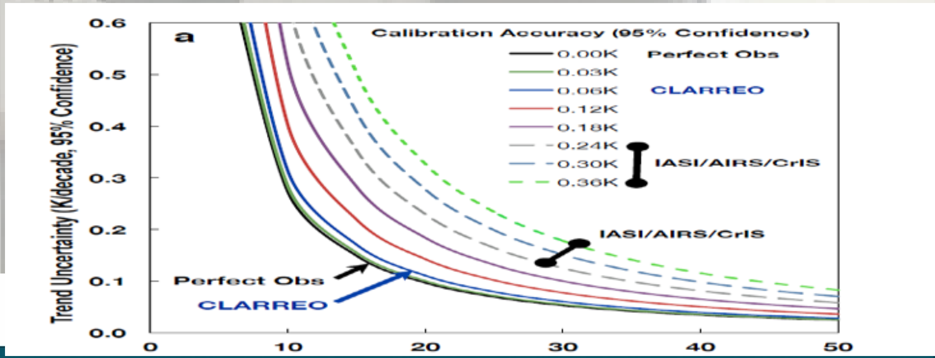
Calibrations and Uncertainties evaluations
to reach full comparability



- Comparability on climate-change scales
- Comparability to fundamental physical models
- Comparability across generations
- Comparability across borders & organizations
- Comparability across instrument/measurement types

Accurate Measurements

to Reduce the Time Necessary to Capture a Trend



The Project

METEOMET

Metrology for Meteorology

(ENV58 as follow-up of ENV07)

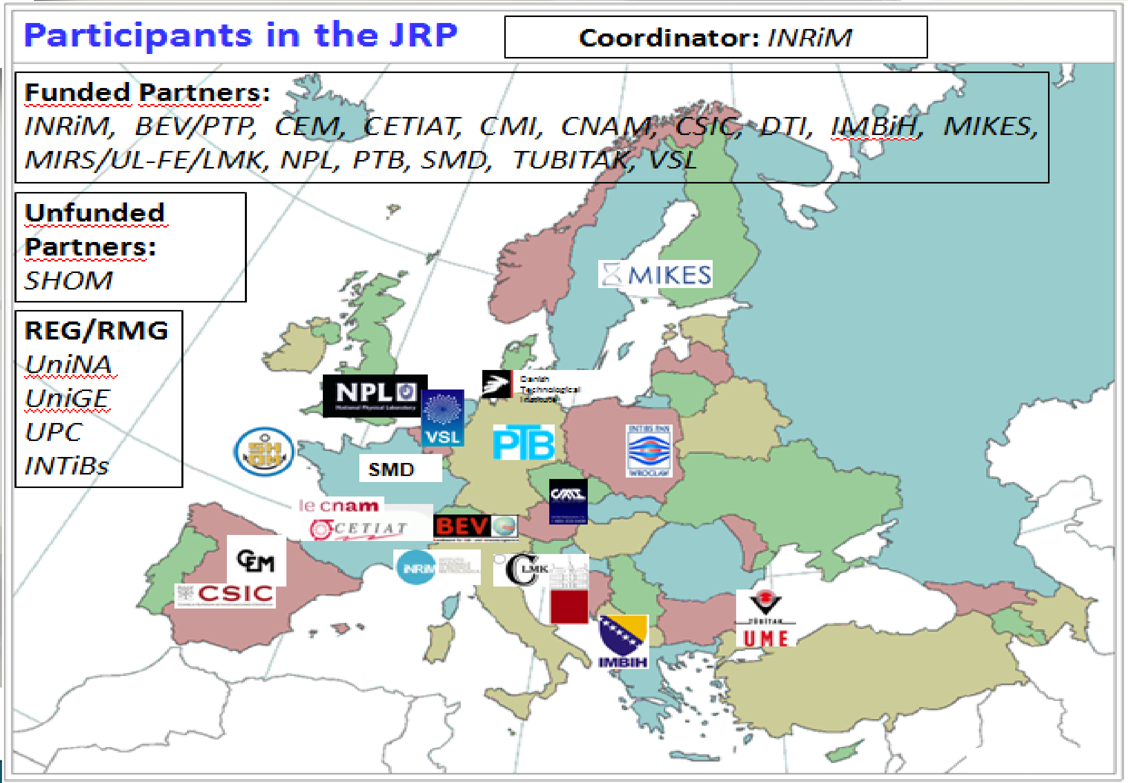
11 M€ Budget

300 Deliverables

960 Man months

(80 years!)

Together with ENV07



Introduction

Companies

Universities

Institutions

B1.a Summary of the JRP

The preceding EMRP JRP, ENV07 MeteoMet, covered a wide range of needs for traceability and calibration in meteorology. On the basis of the results and experience achieved, this JRP extends to further objectives: from meteorological sensor calibration uncertainties to evaluation of measurement uncertainties, improvement of the previously developed devices and their use in field oriented activities, new investigations on sensor characteristics for the generation of higher quality climate data; extension of the atmospheric **Essential Climate Variables** (ECVs) to include soil and oceanic ECVs. The ECVs considered in this JRP are: water vapour in upper-air and surface atmosphere, surface and deep sea temperature and salinity, air temperature, precipitation, albedo, permafrost temperature and soil moisture.

Water vapour, amongst upper-air ECVs, is certainly a challenging quantity to measure. Reliable measurements require sensitive sensors with fast response time, able to quantify the wide dynamic range and the fast changes.

Two of the oceanic ECVs having a main role in the monitoring of oceans are temperature and salinity. High quality instruments exist, or are being developed to perform accurate measurements of these quantities in sea water. However, a comprehensive study of the effect of the main quantities of influence on thermometers and salinometers is needed, in order to determine corrections for these effects, with the aim of either reducing measurement uncertainty, or to realise a metrologically validated characterisation.

Focusing on air temperature, a consistent measurement uncertainty calculation needs a complete knowledge of the measurement system, starting with its intrinsic behaviour, the influence of the place where the measurements are performed and the influence of other meteorological parameters such as albedo and precipitation.

The air temperature measured by AWSs depends strongly on the indirect sun reflexion by the ground, mainly in snow areas. The traceability and a reliable uncertainty calculation of the albedo are needed in order to have a better control of the air temperature measurements, especially in high mountain sites.

Due to a lack of satisfactory calibration standards regarding precipitation, the meteorological community requested further studies on traceability and uncertainty calculation during JRP ENV07 MeteoMet and part of which are included here.

Soil moisture measurements are essential in understanding water vapour interchange between land and air, directly influencing meteorology, earth observation, hydrology, agriculture and management of flood risk. However, soil moisture measurement accuracy is weak, affected by soil structure and interferences and traceable calibration methods are not yet well enough developed to solve these problems.

This JRP aims to develop metrological **traceability** for the measurement of main ECV defined by GCOS [1] and is structured in 3 technical WPs, each covering a different area of observation: Air, Sea and Land.

WP1 Air is devoted to providing suitable calibration facilities and procedures for humidity sensors working under actual measurements conditions in response to needs expressed by GRUAN in its fundamental operational guide published as WMO WIGOS report (pages 34, 41, 46, 53, 75 in [2]).

Radiosondes are fundamental measurement tools to detect atmospheric data in the upper atmosphere. Facilities for calibration at low temperature and pressure will be developed and compared to obtain a

ECVs

Domain	GCOS Essential Climate Variables
WP1 **AIR**	**Surface:** Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget. **Upper-air:** Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance). **Composition:** Carbon dioxide, Methane, and other long-lived greenhouse gases[3], Ozone and Aerosol, supported by their precursors[4].
WP2 **SEA**	**Surface:** Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton. **Sub-surface:** Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.
WP3 **LAND**	River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture.

Publishable summary – January 2016 – Air

Developing metrological procedures to calibrate radiosondes under atmospheric conditions including reduced pressures and temperatures. (D1.1.x)
The humidity calibration system for radiosondes has been developed further by MIKES to extend the operation to low pressures (down to 10 hPa) and to improve the performance at low temperatures (-80 °C). The effect of low pressure on the system has been studied by numerical simulations and experiments. The design of an INRIM calibration facility for airborne upper air reference instruments to cover the frost point temperature range from -20 °C to -95 °C was completed.

Improving atmospheric water vapour level measurements by measuring enhancement factors under atmospheric conditions i.e. reduced pressure and temperature. (D1.2.x)
The activities are at an early stage but they are on time and in progress at CETIAT. A literature review is under way in order to identify advantages and drawbacks of different experimental facilities

Further development of spectroscopic techniques (TDLAS, CRDS) as possible basic standard for traceable atmospheric measurements and as on-site reference. (D1.3.x)
A report on typical uncertainty constraints of airborne hygrometers is in progress at PTB. Other planned activities of this topic are on-time, just started, or will be started in the next period.

Publishable summary – January 2016 – Air

Development of a traceable calibration source capable to provide on-site calibration of airborne instruments. (D1.3.x)
A mobile, compact and robust water vapour generator, which uses water permeation through air-purged plastic tubing is currently being developed further and manufactured. By stabilising gas flow and bath temperature a well-defined mixing ratio can be maintained. The First Performance tests are already ongoing. A calibration at a primary water standard is planned.

Development of a reference instrument for measurement of rapid transients of temperature and humidity in free space. (D1.4.1-2)
Work has started on improving the rate of data acquisition for both a spectrometer and an acoustic thermometer. The existing technique is adapted to optimise the speed of response. Components have been obtained (A to D converter and processor card) and approaches have been identified to improve the speed and scalability of the temperature measurements. The water vapour spectrometer has been adapted and is being trialled at a reading rate in the order of 100 Hz. (NPL, INRIM, CNAM)

Development of a new generation of traceable humidity sensors based on microwave resonators with low response time and small size. (D1.4.3-6)
The first generation of microwave hygrometers is running and has been compared with a reference hygrometer provided by CETIAT. Results have shown a substantial agreement of the measurements, within the calibration uncertainties of the reference hygrometer. After a presentation of the preliminary results at the 19th Symposium on Thermophysical Properties, new data will be shown in Tempmeko 2016. Recently, a second generation of microwave hygrometers has been realised and the assembly of the full system is in progress.

Publishable summary – January 2016 – Sea

•The development of facilities to study the **pressure dependence of deep-sea thermometers** involved the development of a comparison block and a **high-pressure chamber** to simulate deep sea conditions

• Tests demonstrated how an **acoustic gas thermometer** (AGT), is suitable to calibrate deep-sea thermometers in thermodynamic temperature.

•The development of a facility including a high-pressure chamber and a **quasi-adiabatic cryostat** is in progress to characterize salinometers and deep-sea thermometers.

•**A fibre optics structure** has been designed for measuring the profile near the surface of the sea and in sea beds: the system will be calibrated under a specific procedure and will be tested on a marine observatory.

Publishable summary – January 2016 – Land

Air temperature sensors dynamics: instruments collection from several manufactures completed. Recommendation on uncertainty evaluation being prepared for ISO17714:2007 and to CIPM/CCT.

Influence of the siting on air temperature measurements uncertainty: Protocol prepared and sent to the WMO Expert Team on Observation in situ technologies: positive feedback. Three large scale experiments started in three partner nations. Data ready by July 2017 for the WMO Sustained Performance Classification for Surface Observing Stations on Land

Influence of rain and albedo on air temperature measurements. Study started**.**

Comparison of National Meteorological and Hydrological laboratories: protocol ready; Start date: April 2016. WMO evaluating the possibility to perform a comparison in agreement with such protocol.

Procedures for dynamic calibrations of hygrometers for near Earth surface with a uncertainty calculation. Theoretical studies started.

Development of a fast step change humidity generator started The facility will be ready in January 2017

Permafrost simulation laboratory facility. Design started; field calibration site identified and campaign planned.

Survey prepared and launched on soil moisture sensors. Numerous responses collected. Workshop planned

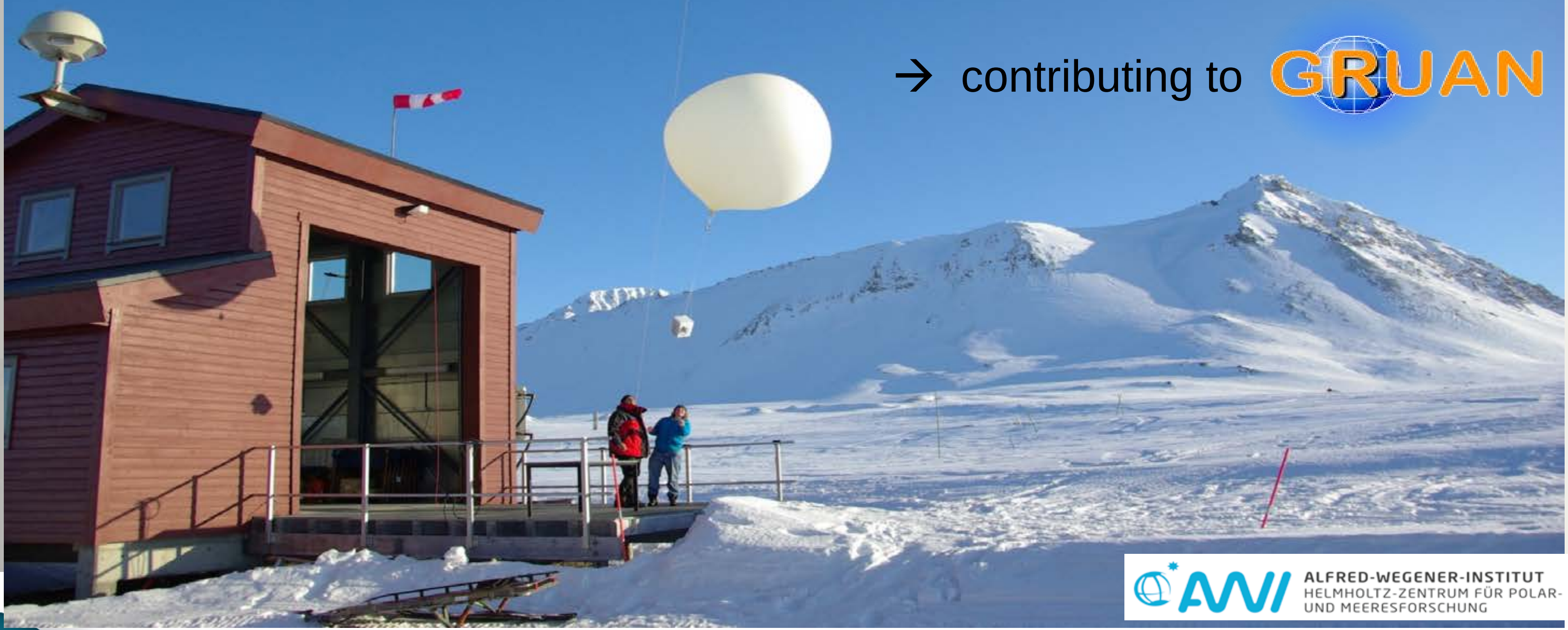
Ny Ålesund campaing

Ny Ålesund campaing

Vertical profiles of T, humidity and wind

Daily Radiosonde Launches

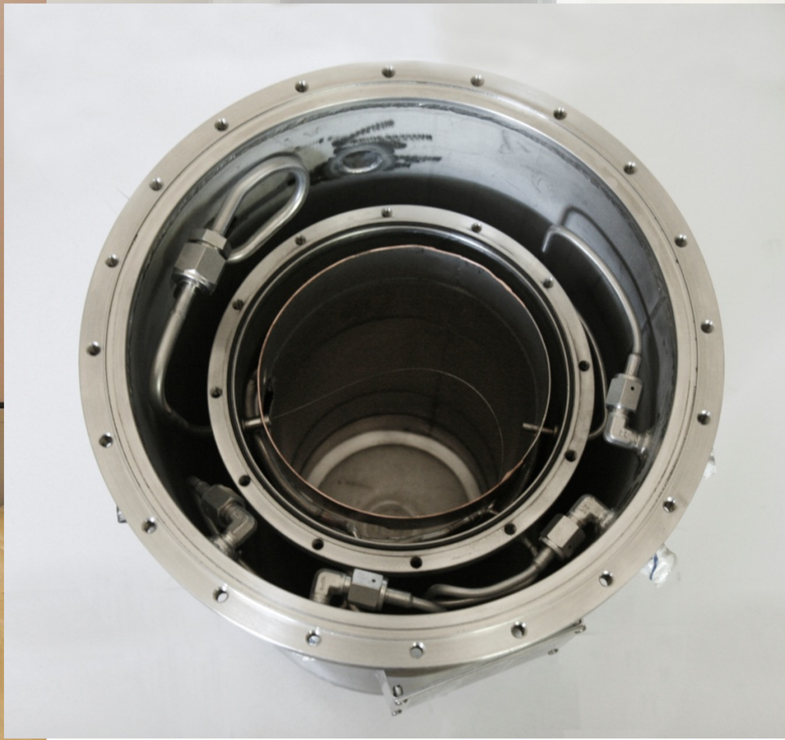
→ contributing to GRUAN



The new portable facility built at INRiM

EDIE-1

Simultaneous calibration of temperature, pressure and humidity



Ny Ålesund campaing

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METEOROLOGICAL APPLICATIONS

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RMetS
Royal Meteorological Society

Arctic metrology: calibration of radiosondes ground check sensors in Ny-Ålesund

Chiara Musacchio,[a]* Simone Bellagarda,[a] Marion Maturilli,[b] Jürgen Graeser,[b] Vito Vitale[c] and Andrea Merlone[a]

[a] *Istituto Nazionale di Ricerca Metrologica Thermodynamics Division (INRiM), Torino, Italy*
[b] *Helmholtz Center for Polar and Marine Research, Alfred Wegener Institute (AWI), Potsdam, Germany*
[c] *Istituto di Scienze dell'Atmosfera e del Clima, Consiglio Nazionale delle Ricerche, Bologna, Italy*

ABSTRACT: The Arctic research village of Ny-Ålesund (79 ° N, 12 ° E) on the Spitsbergen island of Svalbard archipelago, with its logistics and infrastructure, provides a unique access to the Arctic environment. Among the several international environmental and climate monitoring programmes constantly running there, the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) has established one of its stations at the Alfred Wegener Institute observatory. Calibration of sensors and measurement traceability are fundamental aspects of climate observations, as requested by the GRUAN measurement procedures. In the framework of the MeteoMet project, a transportable climatic chamber for the calibrations of air temperature and pressure sensors was studied and manufactured. In June 2014, a calibration campaign involved the transport and use of one of those systems in the Ny-Ålesund GRUAN station. The result of the campaign has

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&

World Meteorological Organization

CIMO-TECO

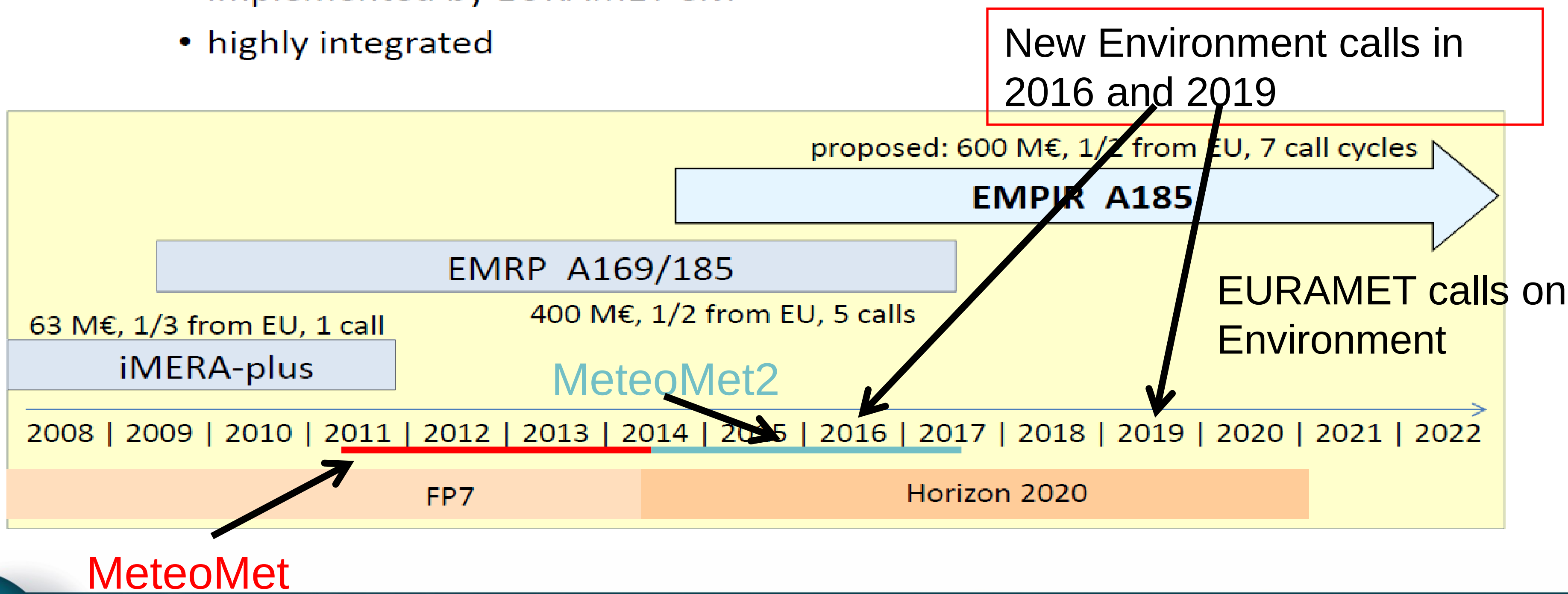
26-29 September 2016
Spain (Madrid)

an occasion to reciprocally increase knowledge and understanding

http://www.mmc-2016.org

Joint programming of metrology research

- coordination of national metrology research programmes (EMRP with those of 22 member states)
- jointly agreed strategic research agenda
- implemented by EURAMET e.V.
- highly integrated



Further collaboration…

A.3. Optional details of co-authors

Co-author	Name	Organisation / Affiliation	Country
1	Andrea MERLONE	INRIM	Italy
2	Morten RASMUSSEN	Danish Technological Institute	Denmark
3	Rigel KIVI	Finnish Meteorological Institute	Finland
4	Peter THORNE	Irish Climate Analysis and Research Units	Ireland
5	Volker EBERT	Physikalisch-Technische Bundesanstalt	Germany
6	Vito VITALE	Institute of Atmospheric Sciences and Climate	Italy
7	Ruud DIRKSEN	Deutscher Wetterdienst	Germany
8	Marion MATURILLI	Alfred Wegener Institute	Germany
9	Hannu SAIRANEN	VTT MIKES	Finland
10	Guido NIGRELLI	CNR-IRPI	Italy
11	Carmen García IZQUIERDO	Centro Espanol de Metrologia	Spain
12	Fernando SPARASCI	LNE-CNAM	France
13	Ragne EMARDSON	SP	Sweden
14	Luca LANZA	University of Genova	Italy
15	Eric GEORGIN	CETIAT	France

Further collaboration…

- Establish a permanent **Arctic Metrology Facility** in a polar research station, to directly link metrological traceability to on site environmental measurements
- Provide new climate **reference data methodologies for key upper atmospheric measurement techniques** including uncertainty assessment, traceability chain and metadata requirements. Implemented in collaboration with the **GCOS Reference Upper Air Network (GRUAN).**
- Address the current performance limits and **improve measurement strategies in ECV measurement capabilities in the climate-sensitive regions** identified.
- Develop **metrology tools to enable robust comparison** between different measurements of the same geophysical parameters including the effect of temporal and spatial co-location differences.

Thanks for your attention and for having me here!