# *Workshop*

# *Soil moisture measurement – challenges in calibration and metrological traceability*

*Wednesday 28 September at IFEMA – Feria de Madrid,*
*in conjunction with WMO CIMO TECO 2106 and MMC 2016*

**Meeting room – Sala Goya**

- What are the needs and challenges for accurate measurement of soil moisture?
- What is the state of the art in soil moisture calibration?
- What does effective calibration mean, for soil moisture measurements? Why is this not easy?
- How can the discipline of metrology help?

This workshop will discuss measurements of soil moisture, focusing on the needs for developments in calibration of measuring techniques, for both in-situ and remote measurements. Expert speakers will present views of the measurement and calibration issues. This will be followed by a structured discussion to identify needs and potential courses of action to improve practical calibrations for soil moisture instruments - what could be done by the combined meteorology and metrology communities.

## Morning session

*Workshop chair, Stephanie Bell, National Physical Laboratory, UK*

09:15 **Arrival and registration**

09:30 **Welcome, introduction, purpose and format of the workshop**
*Stephanie Bell, Lead Scientist Humidity and Moisture, NPL, UK*

09:50 **The MeteoMet Project - a short introduction**
*Andrea Merlone, INRIM, Italy*

10:00 **Soil Moisture Calibration: Issues for Consideration**
*John Newstead, Soil Scientist, Delta-T Devices, UK*

*10:30 – 11:00 break, coffee*

11:00 **Calibration and Measurement Uncertainty for Soil Moisture Instruments for Agriculture and Survey Results**
*Francesca Sanna, Plant biotechnologist in metrology for agrometeorology, INRIM, Italy*

11:30 **Uncertainty Analysis of Soil Moisture Estimates through Dielectric Methods**
*Paolo Castiglione, Research Scientist, Decagon Devices Inc. and Washington State University, USA*

12:00 **Soil Moisture in a "Sunburnt Country"**
*Jane Warne, Bureau of Meteorology, Australia*

(Continued overleaf)

12:30 **Metrology View – BIPM, the SI, Measurands, Metrological Traceability and Uncertainty of Measurement**
*Stephanie Bell, Lead Scientist Humidity and Moisture, NPL, UK*

*13:00 – 14:00 break, lunch*

## Afternoon session

14:00 **Survey of Requirements for Metrological Traceability for Measurements of Soil Moisture Content**
*Stephanie Bell, Lead Scientist Humidity and Moisture, NPL, UK*

14:30 onwards **Discussion - Soil Moisture Measurement - Challenges in Calibration and Metrological Traceability**
*Chair Stephanie Bell, NPL, UK*

Structured discussion and capture of issues and ideas:
Theme - effective soil moisture measurements with fit-for-purpose calibration and metrological traceability
Aims of discussion:

- identify calibration needs, and barriers
- identify strategic approaches to improve the state of the art
- identify potential actions

*15:30-16:00 break*

17:00 *Approximate end time*

## Workshop: Soil moisture measurement – challenges in calibration and metrological traceability

## Abstracts

### Soil Moisture Calibration: Issues for consideration

*John Newstead, Soil Scientist, Delta-T Devices, UK*

The ability to produce calibrations for soil moisture monitoring is not a pre-requisite for the use of soil moisture sensors but allows the absolute measurement of the water status of a soil or substrate. This is important in water use efficiency or water balance studies and precision irrigation in particular. However, there are many problems with the production of calibrations or possible standards not least the inherent variability in natural soils and the approximation of equations used. However, with the greatest source of error coming from poor installation and practice and potentially much larger errors from other ancillary equipment such as irrigation booms, we are reminded that best practice should always be adhered to when installing and using such sensors to reduce these overall errors.

### Calibration and measurement uncertainty for soil moisture instruments for agriculture

*Francesca Sanna, Plant biotechnologist in metrology for agrometeorology, INRIM, Italy*

Soil water content has an important role for agriculture and agricultural science. Most physical and chemical properties of soil vary with moisture content. Measurement of soil moisture is needed in every type of soil study and applications. For agricultural purposes in particular, depending upon the soil-moisture-plant environment, is essential in crop production. For determining the soil moisture content, various techniques are employed for both the laboratory and in situ measurements. However, both classical and modern techniques used in agrometeorological studies and applications there is the need for an improvement of measurement and calibration uncertainty evaluation, related to the accuracy, precision, coverage and volume of measurements.
In order to better understand how face this issue, a literature research on soil moisture measurement and calibration methods focused in agriculture was conducted. Moreover, a soil moisture questionnaire was designed and distributed by the project partners to their contacts, to address the applications of soil moisture measurements, measurement techniques, their calibration methods, classical gravimetric method and remote sensing techniques. The sectors of these contacts cover academia, industry, government organisations and manufacturers. A summary of main results will be presented.

### Uncertainty Analysis of Soil Moisture Estimates through Dielectric Methods

*Paolo Castiglione, Research Scientist, Decagon Devices Inc. and Washington State University, USA*

The greatest challenge in estimating water content through dielectric methods derives from soil permittivity being sensitive not only to the volumetric fraction of water, but also to a number of additional quantities. These include both structural, such as texture and bulk density, and environmental factors, such as pore water solute concentration and temperature, among others. As a result, any attempt to predict water content from soil permittivity will not lead in general to exact estimates, even if we were capable of error-free dielectric measurements. We can define the resulting errors in water content estimates as correlation error. Such uncertainty is evaluated for two popular techniques, Time Domain Reflectometry (TDR) and capacitance sensors. To that end, we developed a novel physical model for soil permittivity and generated synthetic dielectric data, as obtained through ideal TDR and capacitance sensors, for a variety of soil types, environmental conditions and moisture values. As the analysis reveals, a one-point estimate of dielectric (i.e. at a single frequency or involving apparent permittivity) is not an ideal predictor, i.e. it does not contain enough information to predict water content accurately for all soils and under all possible environmental conditions. A basic statistical analysis of synthetic data allowed us to quantify the errors associated with each technique. Finally, we will discuss soil specific calibration procedures, often adopted to mitigate structural uncertainty, and the associated problem of attaining reference soil moisture values.

**Metrology view – BIPM, the SI, measurands, metrological traceability and uncertainty of measurement**

*Stephanie Bell, NPL, UK*

Metrology is the science of measurement, including all theoretical and practical aspects of measurement. It deals with definition of internationally accepted units and scales of measurement, and realisation of these units and scales in practice. It addresses metrological traceability – the use of a chain of calibrations linking measurements made in practice to reference standards. It also covers evaluation and expression of measurement uncertainty according to internationally agreed practices. The presentation will give an overview of metrology principles, and their relevance in the context of soil moisture measurement. As well as illustrating some best practice, this will aim to show how a metrology perspective can clarify our view of a measurement problem.

**Survey of requirements for metrological traceability for measurements of soil moisture content**

*Stephanie Bell, NPL, UK*

A survey of users of soil moisture measurements has been carried out as part of MeteoMet2. The online questionnaire was answered by more than 100 respondents with interests spanning agriculture, weather and climate, hydrology, geotechnical engineering, soil erosion, and others. Questions covered soil moisture measurement applications, soil types, techniques used, measurement geometry, calibration methods, and measured value range and units, and estimated uncertainties. There were also optional questions covering remote sensing of soil moisture. A number of comments were also made by respondents. A summary of the survey results will be presented, giving an overview of expressed interests in calibration for measurements of soil moisture content.