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DOE/SC-ARM-TR-261

Multi-Element Water Content System Instrument Handbook

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November 2020

ARM

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Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

AAF	ARM Aerial Facility
ACAPEX	ARM Cloud Aerosol Precipitation Experiment
ARM	Atmospheric Radiation Measurement
ASCII	American Standard Code for Information Interchange
CAPS	cloud aerosol and precipitation spectrometer
CSIRO	Commonwealth Science and Industrial Research Organisation (Australia)
DAQ	data acquisition system
DC	direct current
HI-SCALE	Holistic Interactions of Shallow Clouds, Aerosols, and Land-Ecosystems
IWC	ice water content
LWC	liquid water content
netCDF	Network Common Data Format
PVM	particle volume monitor
SEA	Science Engineering Associates, Inc.
TWC	total water content
UTC	Coordinated Universal Time

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1.0 Instrument Title

WCM-2000: Multi-Element Water Content System

The current name in the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility's online Data Discovery tool is: 1.1.1 IOP Data: wcm

2.0 Mentor Contact Information

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3.0 Vendor/Developer Contact Information

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General Information: info@scieng.com

4.0 Instrument Description

The SEA Model WCM-2000 multi-element water content system was designed to provide aircraft and wind tunnel users with a single, rugged sensor to simultaneously measure liquid water content (LWC), total water content (TWC), and ice water content (IWC). The instrument consists of four heated stainless steel elements, each with a different shape or size. Each element is directly heated by low-voltage DC current flowing through the element. These elements are maintained at a constant temperature, typically 140°C, by a digital closed-loop control system. Three of the heated elements are exposed directly to the airstream and incoming cloud water. A fourth element, the reference/comp element, is arranged to be exposed to the airflow but not to incoming cloud water. This element is used to establish the "dry power term" that is subtracted from the other three elements' power readings to establish the measured water content.

The instrument makes two independent measurements of LWC using two different-diameter LWC elements. The small LWC element is the same diameter, 0.5 mm, as the classic JW/CT LWC sensor. The second element is the same size, 2 mm, as the Australian Commonwealth Science and Industrial Research Organisation (CSIRO) (King) LWC sensor. Wind tunnel tests have shown that the two LWC elements have less than 1% false response to IWC in the airstream. This compares favorably to wire-wound LWC elements, which typically have a false response to IWC of 10 to 20%.

The instrument uses a scoop-shaped sensor to collect and measure both LWC and IWC. The combined total of LWC and IWC is referred to as TWC. By subtracting the LWC measured by the LWC elements from the TWC measured by the scoop element, the IWC can be calculated.

Figure 1. The sensor of the multi-element water content system.

5.0 Measurements Taken

This instrument measures total water content, and two measurements of liquid water content.

6.0 Links to Definitions and Relevant Information

The vendor manual for this instrument can be found at: http://www.scieng.com/products/multi.htm

6.1 Data Object Description

The archived ARM data are available in both netCDF format and ASCII format. The raw data are collected via a control unit embedded into an SEA m300 data acquisition system (DAQ) time-synced to the main SEA m300 DAQ. The data file column definitions are provided in Table 1.

Other water content instruments aboard the ARM Aerial Facility (AAF)'s manned platform are the particle volume monitor (PVM-100a) and the cloud aerosol and precipitation spectrometer (CAPS) hotwire. A merged, higher-level data set is available at arm.gov with the name LWC-AIR.

Table 1. Data file column definitions.

Variable	Description
YY/MM/DD HR:MN:SC	Time, UTC
TWC	Total water content, gm^3
LWC083	0.5 mm diameter element, Liquid water content, gm^3
LWC021	0.2 mm diameter element, Liquid water content, gm^3

6.2 Data Ordering

Data from the WCM-2000 can be accessed and ordered on the ARM website. Data are organized by measurement location and campaign. Data objects are given the name 'wcm-air' or 'aafwcm' depending on how data were ingested, but the content is the same.

6.3 Data Plots

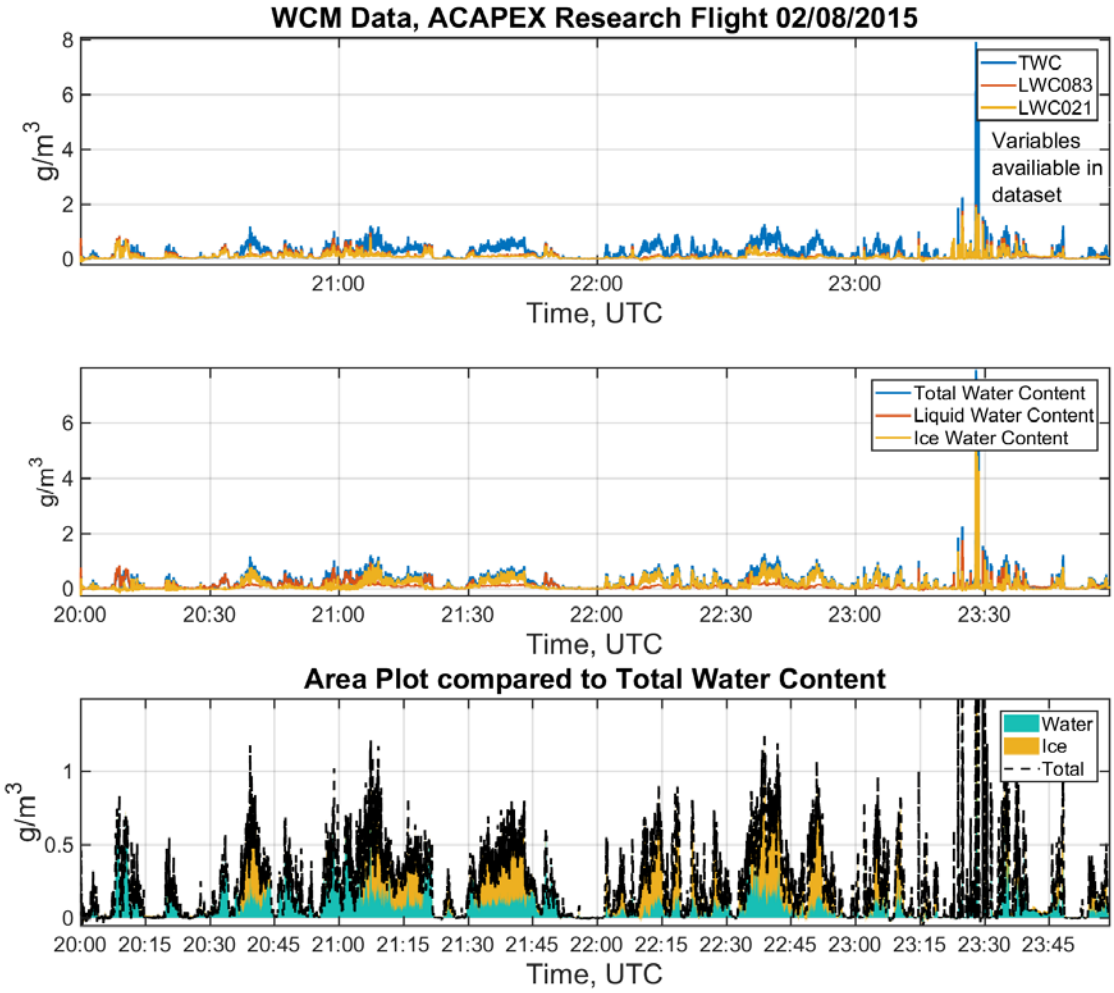

Figure 2. Time series of WCM data from the ARM Cloud Aerosol Precipitation Experiment (ACAPEX). Ice water content is determined by subtracting the liquid water content from the total water content.

7.0 Technical Specification

7.1 Units

Water content is expressed in g/m^3.

7.2 Range

Typically, the measurements will fall within a range of 0−2 g/m^3 but may go up to 10 g/m^3. Data are reported at 1 Hz.

7.3 Accuracy

Wind tunnel tests have shown that the two LWC elements have less than 1% false response to IWC in the airstream.

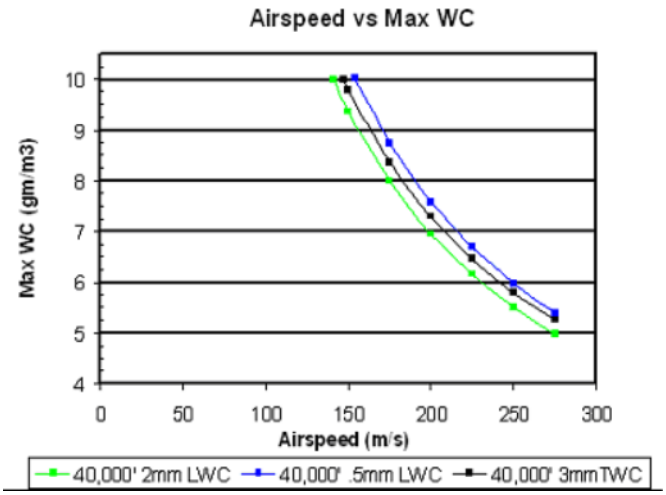

Figure 3. Wind tunnel test results of WCM accuracy.

7.4 Uncertainty

Under extremely cold and humid conditions the WCM can freeze up. This will result in an unreal spike in the data. Use auxiliary LWC measurements taken on the aircraft to validate. The data are also unreliable during takeoff and landing.

8.0 Instrument System Functional Diagram

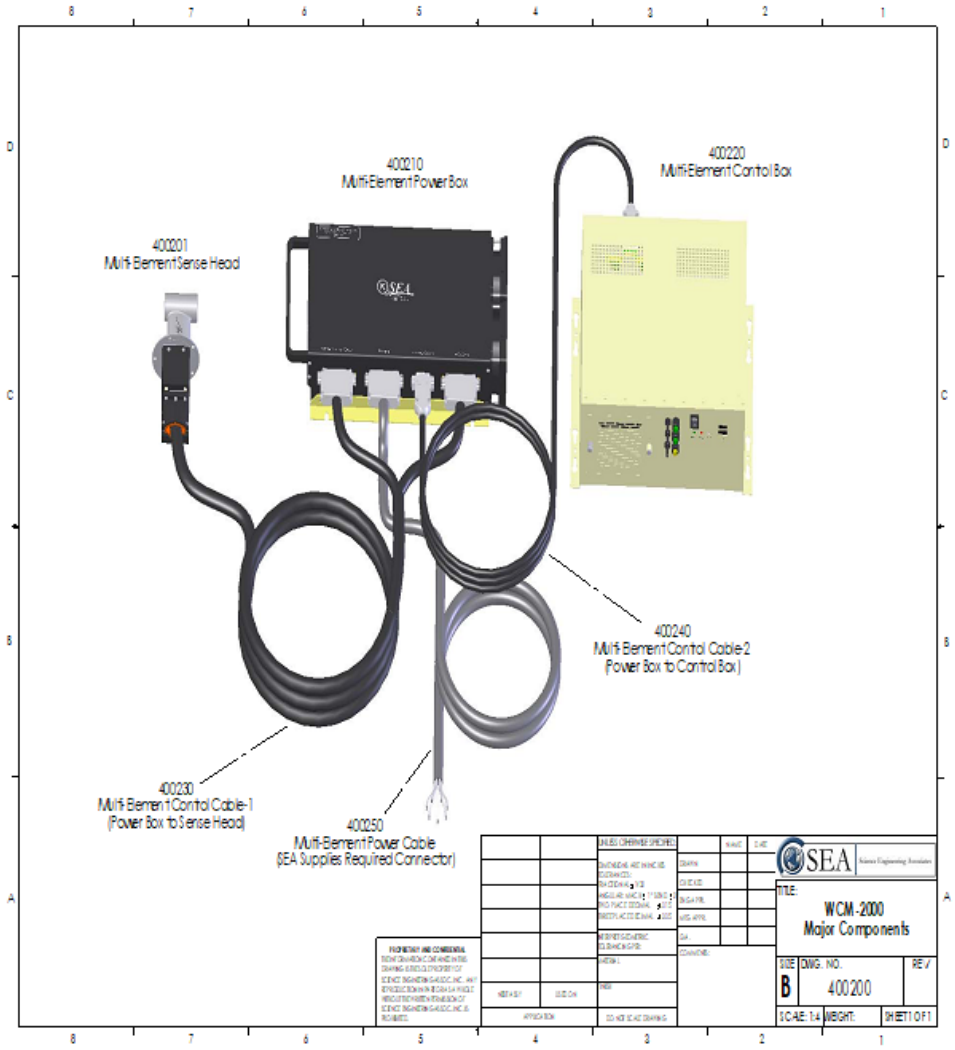

Figure 4. WCM instrument system functional diagram (from the manufacturer's website).

The sensor head is installed on a strut on the fuselage of the aircraft unimpeded in the free stream. The power box and control unit are installed inside the cabin.

9.0 Instrument Measurement Theory

The sensor head contains four heated stainless steel elements each of different size or shape for the purpose of measuring solid and/or liquid water suspended in the atmosphere. Each element is heated by a low-voltage DC current flowing through the element maintaining a constant temperature (typically 140 deg C) via a digital closed-loop control system. The power required by the control system to maintain constant temperature for each element is directly related to the water content of the airstream and can be converted to grams per meter cubed using the dimensions of each element and the true airspeed of the airflow.

The first element is a scoop designed to collect and measure both liquid water and ice crystals, thereby measuring total water content. The second and third elements are wires of differing diameters. The small LWC element is the same diameter, 0.5 mm, as the classic JW/CT LWC sensor. The second element is the same size, 2 mm, as the CSIRO (King) LWC sensor. All three of these elements are placed perpendicular to the free stream of air. The final element is a reference element positioned to be exposed to the airflow but not to incoming cloud water. This element is used to establish the "dry power term" that is subtracted from the other three elements' power readings to establish the measured water content.

10.0 Setup and Operation of Instrument

Please see the user's guide for this instrument.

11.0 Software

The instrument runs on an SEA M300 system. For details, see the vendor website.

12.0 Calibration

The WCM-2000 is calibrated according to the manufacturer's instructions, which involve a dedicated test flight in cloud-free air. In flight, in clear air, fly three different altitudes at three different speeds to calibrate. Each flight is also corrected for zero-offset bias using clear-air measurements. An example calibration plot is shown below for ARM's Holistic Interactions of Shallow Clouds, Aerosols, and Land-Ecosystems (HI-SCALE) campaign in Oklahoma.

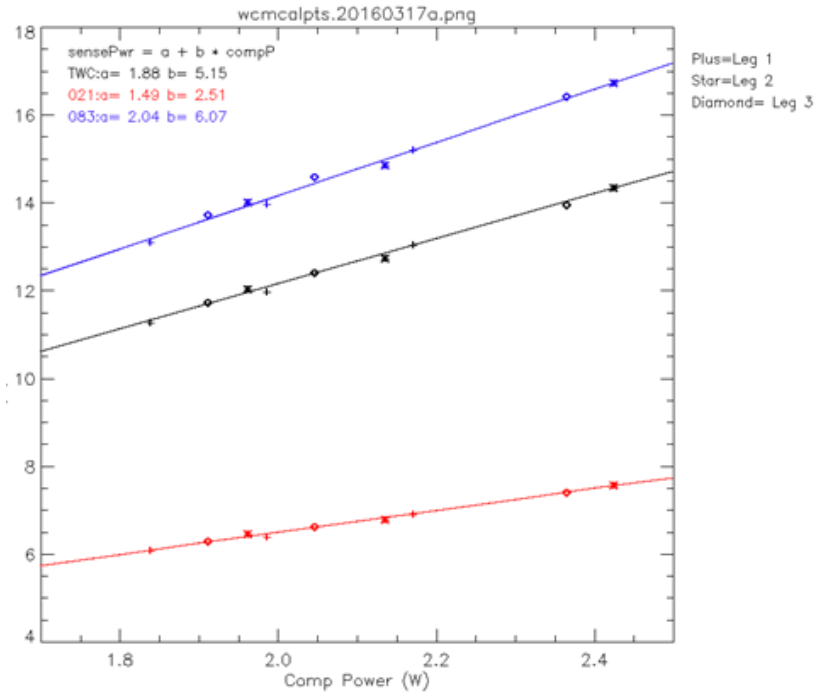

Figure 5. An example calibration plot for the WCM for the ARM HI-SCALE field campaign.

13.0 Maintenance

This instrument should have the wires and scoop cleaned prior to each flight with a dry Q-tip to remove any insects that may have become stuck to the wires.

14.0 Citable References

Vendor website: Science Engineering Associates, Inc. http://www.scieng.com/products/multi.htm

www.arm.gov

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