

# Cloud, Aerosol and Precipitation Spectrometer (CAPS)



*CAPS Probe; photo courtesy of British Antarctic Survey.*

This multipurpose particle spectrometer includes three DMT instruments plus temperature and relative humidity sensors that are packaged into a single, integrated measurement system. The CAPS provides the following data:

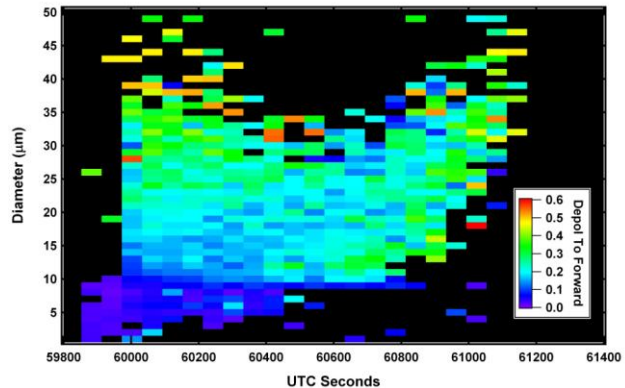
- Aerosol particle and cloud hydrometeor size distributions from 0.51 to 50  $\mu\text{m}$
- Precipitation size distributions from 25  $\mu\text{m}$  to 1550  $\mu\text{m}$ , or 15-930  $\mu\text{m}$  with optional 15-micron resolution
- Particle optical properties (refractive index)
- Particle shape assessments (discrimination between water and ice for probes with depolarization feature)
- Liquid water content from 0.01 to 3  $\text{g}/\text{m}^3$
- Aircraft velocity
- Atmospheric temperature and pressure

This instrument replaces the older PMS/PMI FSSP-100, FSSP-300, 2D-C, 2D-P and KLWC and can be used in many applications, including weather modification, aircraft icing, hurricane and storm research, and agricultural and industrial spray characterization.

## Depolarization Feature

The CAPS with depolarization (CAPS-DPOL) can differentiate between water and ice particles for particles in the 0.5 - 50  $\mu\text{m}$  range. A standard CAPS measures the forward and back-scattered light from these particles, while the CAPS-DPOL measures forward-scattered light and the S-state and P-state polarizations with two backscatter detectors. For spherical particles, typically droplets, the polarization of the incident light will be retained and the crossed polarization in the back-scatter will not generate any signal. Depending on the asphericity of the particles, there will be increased signal in the backscatter detector with the crossed polarizer.

*Photo at right:* Depolarization ratio measured by CAS-DPOL in AIDA cloud chamber showing freezing of water droplets (dark to light color changes).



## Advantages

- Combines multiple instruments in one flight canister, covering a sizing range from 0.51  $\mu\text{m}$  to 1550  $\mu\text{m}$  (or 0.51  $\mu\text{m}$  to 930  $\mu\text{m}$  for a 15- $\mu\text{m}$  resolution CIP), plus Liquid Water Content, Temperature and RH sensing
- Generates 2-dimensional images of particles from 25 - 1550  $\mu\text{m}$
- Provides airspeed and altitude measurements from the heated Pitot tube
- Offers optional depolarization feature that provides information on particle shape

## Applications

- Cloud particle research
- Climate studies
- Aircraft icing
- Weather modification
- Contrails and contrail-induced cirrus
- Cloud chambers
- Spray characterization

*Photo at Right: CAPS mounted on a Twin Otter.  
Photo courtesy of British Antarctic Survey.*



## Principle of Operation

The three DMT instruments included in the CAPS are the Cloud Imaging Probe (CIP), the Cloud and Aerosol Spectrometer (CAS), and the Hotwire Liquid Water Content Sensor (Hotwire LWC).

The CIP, which measures larger particles, operates as follows. Shadow images of particles passing through a collimated laser beam are projected onto a linear array of 64 photodetectors. The presence of a particle is registered by a change in the light level on each diode. The registered changes in the photodetectors are stored at a rate consistent with probe velocity and the instrument's size resolution. Particle images are reconstructed from individual "slices," where a slice is the state of the 64-element linear array at a given moment in time. A slice must be stored each time interval that the particle advances through the beam a distance equal to the resolution of the probe. Optional grayscale imaging gives three levels of shadow recording on each photodetector, allowing more detailed information on the particles.

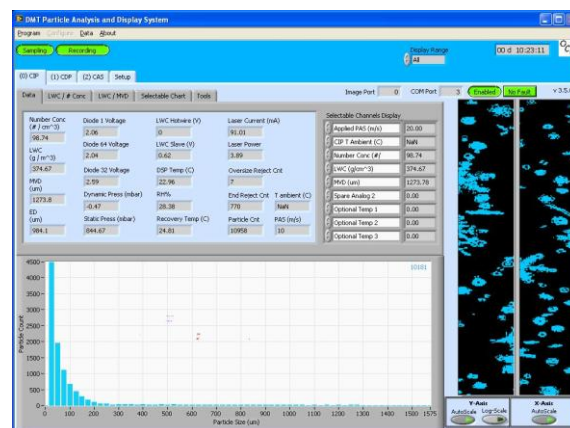
The CAS, which measures smaller particles, relies on light-scattering rather than imaging techniques. Particles scatter light from an incident laser, and collecting optics guide the light scattered in the 4° to 12° range into a forward-sizing photodetector. This light is measured and used to infer particle size. Backscatter optics also measure light in the 168° to 176° range, which allows determination of the real component of a particle's refractive index for spherical particles.

The Hotwire LWC instrument estimates liquid water content using a heated sensing coil. The system maintains the coil at a constant temperature, usually 125 °C, and measures the power necessary to maintain this temperature. More power is needed to maintain the temperature as droplets evaporate on the coil surface and cool the surface and surrounding air. Hence, this power reading can be used to estimate LWC. Both the LWC design and the optional PADS software contain features to ensure the LWC reading is not affected by conductive heat loss.

## Software

The Particle Analysis and Display System (PADS) is optional software that provides a user-friendly virtual instrument panel for the control, data display, logging, and playback of the CAPS instrument. For instance, the program enables the user to do the following tasks:

- Start data recording and sampling
- View particle image data acquired with the CIP
- View particle volume and number concentrations, as well as Median Volume Diameter (MVD) and Effective Diameter (ED)
- View LWC as measured or calculated by the hotwire sensor, CIP, and CAS
- Monitor instrument parameters like CIP laser current and various electronics voltages
- Play back data for post-flight viewing



PADS Software

## CAPS Specifications

	<i>CIP (for 25-<math>\mu</math>m resolution CIP)</i>	<i>CAS*</i>	<i>Hotwire LWC</i>
Technique:	Optical Array Probe with 64 elements: 62 sizing elements, end diodes reject	Forward and Back Scatter Light Sensors	Temperature-Controlled Hotwire Sensor
Measured Particle Size Range:	12.5 $\mu$ m – 1.55 mm (standard)	0.51 $\mu$ m to 50 $\mu$ m	N/A; measured LWC range is 0 - 3 g/m <sup>3</sup>
Sample Area:	10 cm x 1.55 mm	1.1 mm x 120 $\mu$ m	N/A
Upper concentration range	Depends on particle size, but up to 500 particles/ cm <sup>3</sup> for a CIP with standard tips and arm width	Greater than 1,000 particles/cm <sup>3</sup> after corrections for coincidence that are about 25% at 800 and 30% at 1,000 particles/cm <sup>3</sup>	3 g/m <sup>3</sup>
Air Speed Range:	10 – 300 m/sec	10 – 200 m/sec	10 – 200 m/sec
Number of Size Bins:	62	Selectable, 10, 20, 30, or 40	N/A
Sampling Frequency:	1D histogram data: 0.05 to 40 Hz 2D image data: variable interval, when buffer fills	Selectable, 0.05 to 40 Hz	
Laser:	658 nm, 30mW	658 nm, ~50 mW	
Calibration Verification:	Spinning glass disk with opaque dots of known size	Precision glass beads and latex spheres for sub-micron range	Not required
Other	N/A	<ul style="list-style-type: none"> <li>Non-absorbing refractive index, 1.3 – 1.7</li> <li>Light collection angles: 4° - 12°, 168° - 176°</li> </ul>	N/A
Auxiliary Parameters:	Ambient Temperature, Relative Humidity, Static Pressure, Dynamic Pressure (CIP)		
Data System Interface:	2D CIP data: RS-422, High Speed, 4 Mb/sec Baud Rate RS-232 or RS-422, 56.6 kb/sec Baud Rate for system data		
Software:	Particle Analysis and Display System (PADS) (Optional)		
Weight:	45 lbs./20.4 kg		
Power Requirements:	28VDC: 10A for probe system, and 45A for anti-ice heaters, optional AC voltages for anti-ice heaters		
Environmental Operating Conditions:	Temperature: 0 – 40°C (32 – 104 °F) RH: 0 – 100%, non-condensing		
Routine Maintenance:	DMT recommends conducting basic instrument performance checks and inspecting the CIP optical windows before a flight. A weekly calibration check of the CAS and CIP is also recommended.		

Specifications are subject to change without notice. The CAPS is a Class IIIb Laser Product.

\* CAS specifications apply to both standard CAS and CAS-DPOL.

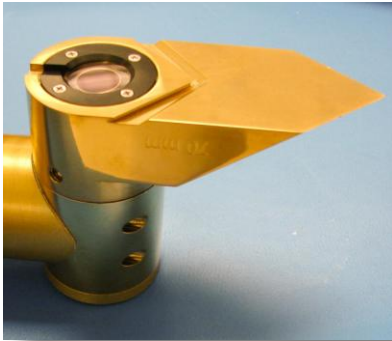
## Calibration

CIP Calibration is verified with a spinning disk (see picture under “Included Items”), while CAS calibration is checked with precision glass beads and latex spheres for sub-micron range. The Hotwire LWC does not require calibration.

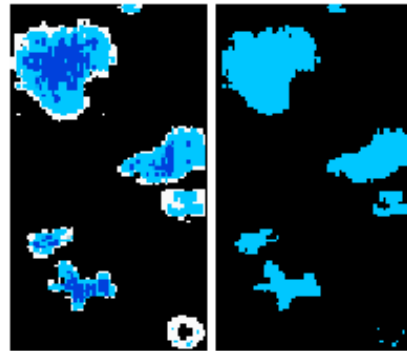
## Options

The CAS is offered with or without the depolarization feature.

The CIP is offered in a 15  $\mu\text{m}$  resolution in addition to the standard 25  $\mu\text{m}$  resolution. In addition, it is offered with standard tips or Korolev anti-shatter tips (below left), and with monoscale or grayscale imaging (comparison shown below right).



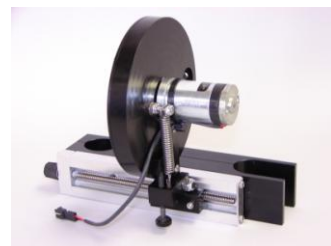
Korolev anti-shatter tips, pictured above, significantly reduce the incidence of particle artifacts in the sample area.



Grayscale imaging (above left) provides detail about particle composition that is missed with monoscale imaging (right).

## Items Included in Purchase Price

- Instrument
- Shipping case
- Operator manual
- Zero-count filter
- Glass beads and dispenser for CAS calibration check
- Spinning disk for CIP calibration check
- One day of training at DMT’s facility
- One-year warranty
- Email and telephone technical support



Spinning Disk to verify CIP Calibration

## Accessories (Purchased Separately)

- PADS software
- Data acquisition system

## Selected Bibliography of CAPS-related Publications

Baumgardner, D., H. Jonsson, W. Dawson, D. O'Connor and R. Newton. "The cloud, aerosol and precipitation spectrometer (CAPS): A new instrument for cloud investigations," *Atmos. Res.* 2001: 59-60, 251-264.

Baumgardner, D., H. Chepfer, G.B. Raga, G.L. Kok. "The Shapes of Very Small Cirrus Particles Derived from In Situ Measurements," *Geophys. Res. Lett.*, 2005: 32, L01806, doi:10.1029/2004GL021300, 2005.

Chiriaco, M., H. Chepfer, P. Minnis, M. Haeffelin, S. Platnick, D. Baumgardner, P. Dubuisson, M. McGill, V. Noël, J. Pelon, D. Spangenberg, S. Sun-Mack, G. Wind. "Comparison of CALIPSO-like, LARC and MODIS Retrievals of Ice Cloud Properties over SIRTa in France and Florida during CRYSTAL-FACE," *J. Appl. Meteor.*, 2007: 46, 249-272.

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Garrett, T.J., H. Gerber, D. Baumgardner, C. H. Twohy, E.H. Weinstock. "Small, Highly Reflective Ice Crystals in CRYSTAL-FACE Anvil Cirrus," *Geophys. Res. Lett.* 2003: 30, NO. 21, 2132, doi:10.1029/2003GL018153

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Heymsfield, A.J., C. Schmitt, A. Bansemer, G-J van Zadelho, M. J. McGill, C. Twohy, D. Baumgardner. "Effective Radius of Ice Cloud Particle Populations Derived from Aircraft Probes," *J. Atmos. Oceanic Tech.* 2006: 23, No. 3, pp. 361-380.

## How to Order

For more information or to obtain a sales quote, contact DMT at 303.440.5576 or [customer-contact@dropletmeasurement.com](mailto:customer-contact@dropletmeasurement.com).



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