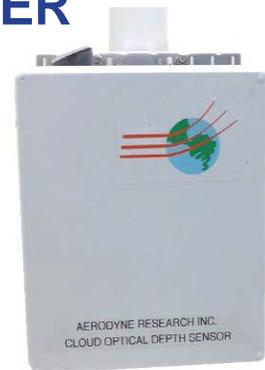




CLOUD PROPERTIES SPECTRORADIOMETER

Three-Waveband Spectrally-agile Technique (TWST)

A real-time cloud properties sensor provides cloud optical depth measurements and retrieval of droplet effective radius and thermodynamic phase. The sensor expands upon the Cloud Mode AERONET algorithm with spectral agility and high temporal resolution while also utilizing the equivalent width of the oxygen A-band to resolve the thick/thin cloud ambiguity



Principle of Operation

A calibrated spectroradiometer stares at a narrow segment (0.5 deg) of the sky directly overhead recording the spectral radiance in the visible wavelength regime at 2 – 8 nm spectral resolution. The relationship between spectral radiance and cloud optical depth (COD) is two-valued; one is in the optically thin region where the brightness increases with increasing COD, and the other is in the optically thick region where the brightness decreases with increasing COD. This ambiguity in COD is the principal complication inherent in the spectral radiance method of measuring COD. Using a spectroradiometer rather than a filter band radiometer allows the instrument to measure the equivalent width of the 760 nm oxygen A-band in order to resolve the COD ambiguity. The equivalent width is a monotonic function of the photon total path length and thus also of the cloud optical depth and does not suffer from this ambiguity.

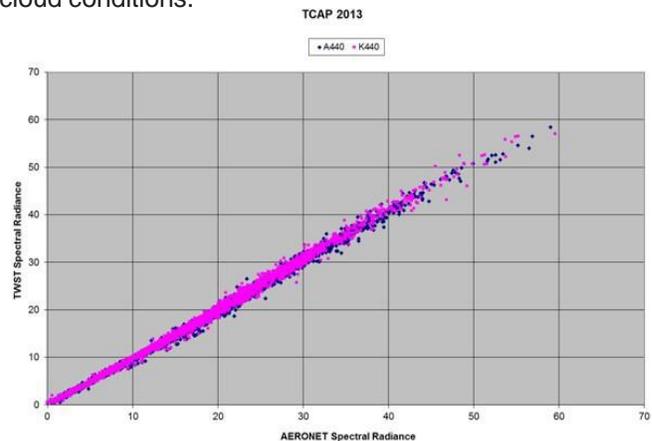
FEATURES

- COD sensitivity better than 0.005 for optically thin clouds
- High Temporal Resolution (up to 10Hz, typical 1Hz, typical SNR > 1000)
- Proven radiometric stability under harsh field conditions; frequent recalibration not required
- Designed for long term autonomous field operation for periods of many weeks* using a sealed IP66 enclosure and backup battery for line power outages
- Delivered sealed, with sun shade, radiometric calibration and a laptop computer fully loaded with executable software for control, data processing and user calibration
- Demonstrated agreement with collocated AERONET Cloud Mode sensors within 1% when comparing in-band solar radiance at 440 and 870 nm

*Periodic cleaning of optical entrance window with distilled water will be needed in some field environments.

APPLICATIONS

- COD is a key parameter in the extensive data base of cloud optical properties required for climatology models.
- Capturing cloud edges and fast evolution of cloud properties; cloud-aerosol interaction effects.
- Ground truth for space-based earth-observing sensors that have insufficient spatial resolution.
- Real-time measurement of COD for any event requiring a 'GO – NO GO' decision based upon knowledge of local cloud conditions.



A comparison of TWST and AERONET Cloud Mode spectral radiances ($\mu\text{W}/\text{cm}^2 \text{ sr nm}$) at 440 nm wavelength.



Specifications

The TWST COD sensor is designed to be robust and transportable for field deployments while providing the user with accurate, real time COD values at a 1Hz data logging rate. The heart of the sensor consists of a single fiber-optic spectroradiometer with an entrance aperture that is well shielded from the sun. Dark spectra collection is done automatically with a conventional shutter. This sensor is unique in providing high temporal resolution (up to 10 Hz), high spatial resolution (0.5 deg), spectral agility and high spectral resolution (6 nm), with typical signal-to-noise-ratio (SNR) > 1000.

Cloud Optical Properties Sensor Specifications For Ambient Temperature Range -10C to +40C	
Weight	20 lbs
Power and Communication for Optical Head	5Vdc, 250 mA via a USB 2.0 connection to host computer for power and data
Size	15" x 13" x 7" plus 12" external sun baffle
Operating Range	Blue sky to COD 100
COD Precision	1% (typical, depends on update rate)
COD Sensitivity	Better than 0.0005 for optically thin clouds
Weatherproof Environmental Container	IP66, NEMA 4X sealed enclosure with desiccant
Precipitation	Slanted optical window design drains water effectively
Data Logging Rate	1 Hz (typical), variable sampling interval from 0.1 to 60 seconds
Field of View	0.5 deg. FWHM
Spectral Range, Resolution	400-800 nm (minimum), ~2-8 nm
Spectral Bands Used in COD Retrieval	440, 760, and 870 or 780 nm



Cloud Properties Spectroradiometer deployed at Department of Energy’s Atmospheric Radiation Measurement user facility, Southern Great Plains site. The instrument is providing in-situ observational data to help better understand the role of clouds in controlling the Earth’s energy balance.

“Application of oxygen A-band equivalent width to disambiguate downwelling radiances for cloud optical depth measurement”. Edward R. Niple, Herman E. Scott, John A. Conant, Stephen H. Jones, Frank J. Iannarilli, and Wellesley E. Pereira. Atmos. Meas. Tech., 9, 4167–4179 (2016)