AERODYNE RESEARCH, Inc.

CLOUD OPTICAL DEPTH SENSOR

Three-Waveband Spectrally-agile Technique (TWST)

A real-time Cloud Optical Depth sensor that 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 TWST 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.

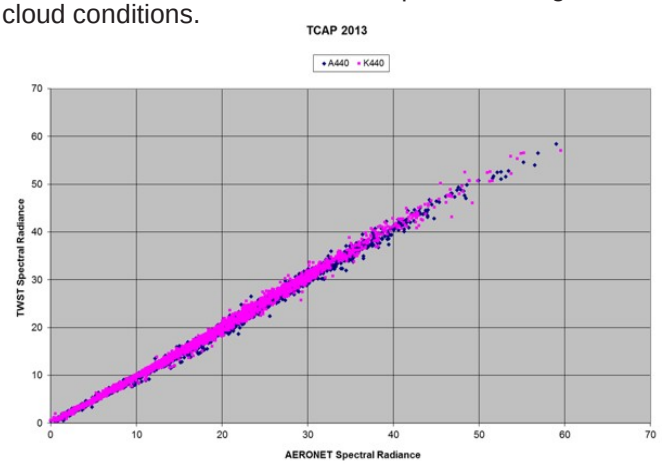
FEATURES

- Typical SNR > 1000
- High Temporal Resolution (up to 10Hz, typical 1Hz)
- Cloud Optical Depth sensitivity better than 0.005 for optically thin clouds
- 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 TWST 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 (μW/cm² sr nm) at 440 nm wavelength.

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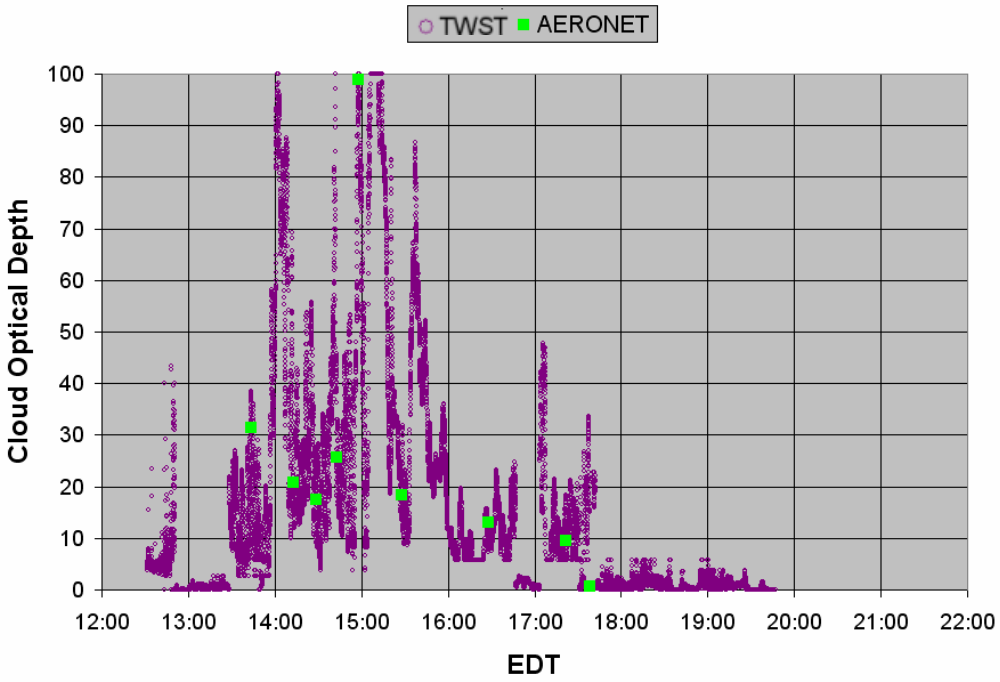
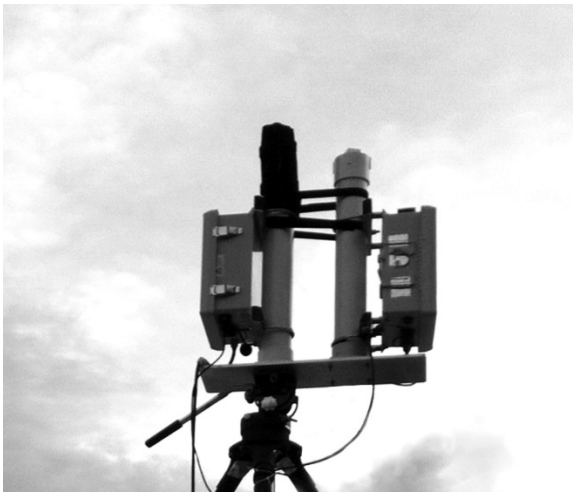
Specifications

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.

TWST Cloud OD Sensor Specifications For Ambient Temperature Range -10°C to +40°C	
Weight	20 lbs
Power and Communication for Optical Head	5 Vdc, <250 ma via a single USB 2.0 cable connection to computer for power and data
Size	11" x 8" x 8" plus 12" external sun baffle; or 13" x 10" x 6" with internal sun baffle
Operating Range	Blue Sky to Cloud OD 100
Cloud OD Precision	1% (typical, depends on update rate)
Cloud OD Sensitivity	Better than 0.005 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 Cloud OD retrieval	440, 760, and 870 or 780 nm



A comparison of Cloud Optical Depths as measured by TWST and AERONET Cloud Mode sensors at the Two Column Aerosol Project** (TCAP), Cape Cod ARM Highland Center site on 12 June 2013.



TWST units deployed side-by-side for check-out testing and calibration purposes.

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**Data were obtained from the Atmospheric Radiation Measurement (ARM) Program Climate Research Facility sponsored by the U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research, Climate and Environment Sciences Division. The Cimel Sun-photometer data were collected by the U.S. Department of Energy as part of the Atmospheric Radiation Measurement (ARM) Program Climate Research Facility and processed by the National Aeronautics and Space Administration's Aerosol Robotic Network (AERONET).

Comparing TWST and AERONET Cloud Mode
at Harvard Forest, Petersham MA, October 3, 2012
Using Independent Data Analysis Techniques