DELTA-Wx Deep Learning Turbulence Sensor, PM-02-600W

Applications

- Passively monitors turbulence conditions
- Laser propagation path characterization
- Modeling and forecasting of propagation conditions
- Atmospheric imaging diagnostics
- Optical communications link performance
- Include turbulence profiles in wave-optics simulations
- Enables custom MATLAB analysis

Unique Advantages

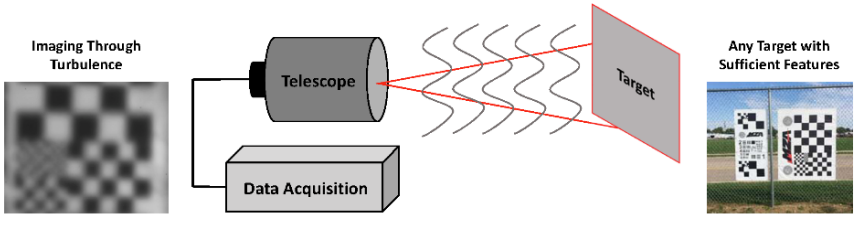
- Bounds C_n^2 turbulence strength along path
- Daily update of weather-driven turbulence modeling
- Download of published numerical weather data
- Application of turbulence model to weather data
- Automatic computation of:
  - Rytov number (scintillation index)
  - Fried's coherence diameter
  - Isoplanatic angle
  - Cross-wind speeds
  - Greenwood and Tyler frequencies
- 2 km range from target to receiver
- Automatic collection, processing, and reporting of turbulence diagnostics, 24/7
- Portable and compact system
- Passive operation—no external sources required for diagnostic target during daytime (IR optional for night)
- Output supports ATMTools, SHaRE, and WaveTrain

Description

MZA's Delayed Tilt Anisoplanatism (DELTA) sensor measures turbulence strength along a line of sight. These turbulent fluctuations, commonly observed as twinkling of distant lights or stars, significantly affect high resolution imaging sensors and can reduce efficiency of laser beam projection for illumination and optical communications. As an upgrade to the DELTA sensor, the "Wx" integrates a weather station with our C_n^2 data acquisition into MZA's Modular Atmospheric Sensor Software (MASS) suite. On a daily basis, the archived turbulence and weather data is taken through the DELTA-Wx machine-learning algorithm. This provides a weather-driven turbulence model which can be applied during subsequent weather measurements or modeling. When applied to standard numerical weather prediction (NWP) data downloaded from internet sources, turbulence forecasts are displayed by the sensor. The output model is also available for use with MZA's propagation modeling software.

Operation

The DELTA system is placed at one end of the path, with a target or object with multiple, trackable features on the opposite end. Depending on the size of the target and the optics on the telescope, a range of ½ to 2 kilometers can be achieved. Once initial setup has been conducted, user desired parameters are adjusted such as feedback period, duration of observation and stored output info. A sequence of imagery is collected and the deviation or "dancing" of feature points on the target is recorded. The DELTA method measures the differential jitter of feature pairs as a function of angular separation. Using multiple pairs at various degrees of separation, a non-uniform C_n^2 profile is estimated using additional atmospheric estimation software. Turbulence statistics are calculated from this profile, as well as cross-wind speeds.



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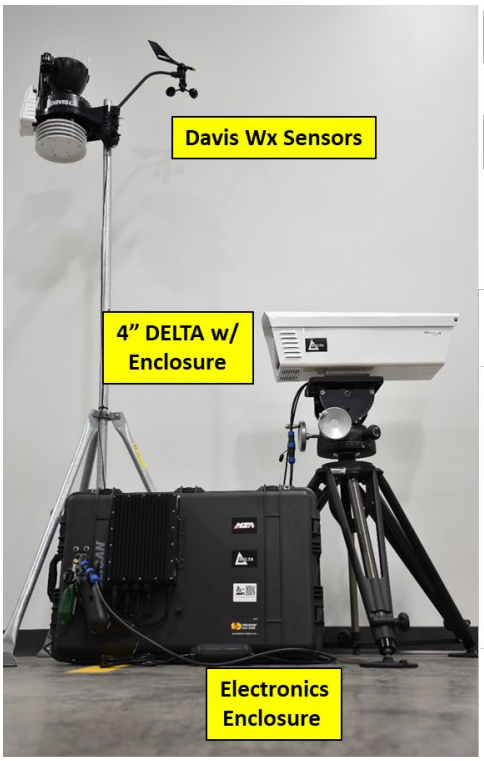
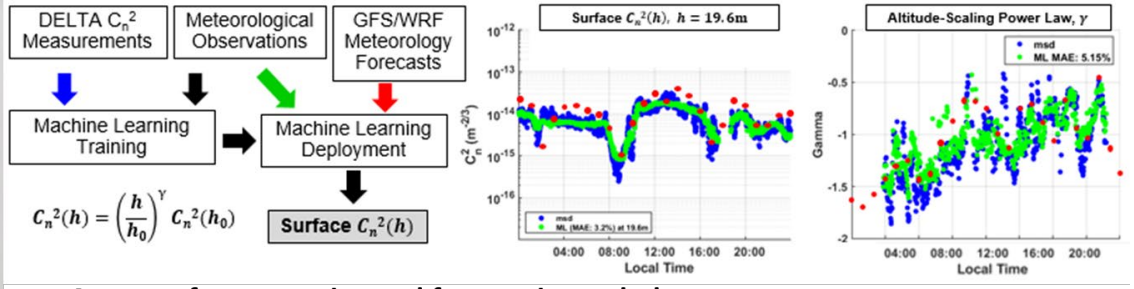
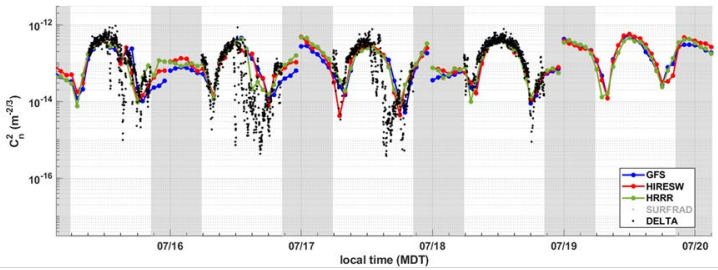
Machine Learning for Weather-Driven Turbulence

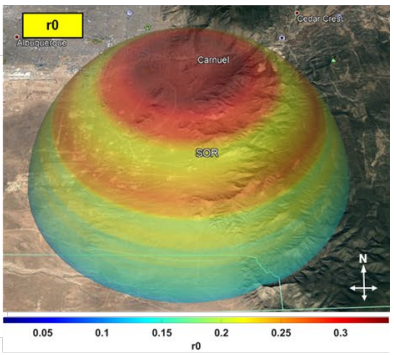
DELTA turbulence measurements, coupled with simultaneous meteorological observations, enable an added MASS software capability for surface-level turbulence modeling. The DELTA-Wx, concurrently measures weather and turbulence and uses machine learning to enhance the surface level turbulence modeling. The machine learning considers standard meteorological inputs (temperature, pressure, etc.) to compute the refractive-index structure parameter, C_n^2. The DELTA-Wx machine learning algorithm processes thousands of meteorological and C_n^2 observations to model their observed physical relationship. By making measurements on an elevated target, DELTA turbulence profiles enable the derivation of near-surface altitude scaling power law, γ (gamma), which is also weather-driven. When DELTA-Wx is deployed, a site-specific turbulence model is automatically generated and continues to learn as new conditions are encountered day-by-day. The output turbulence model is used with ATMTools, SHaRE, and WaveTrain.





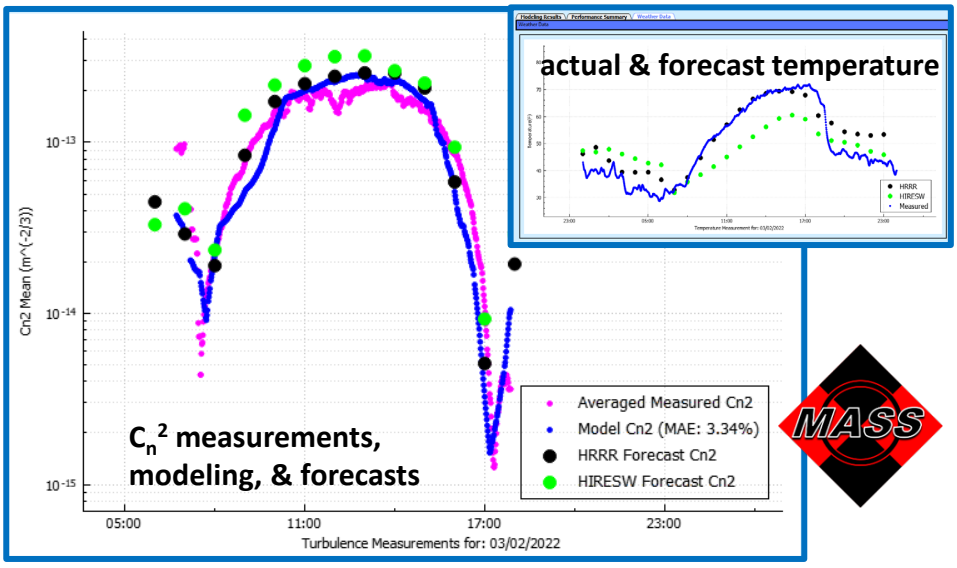
A sensor for measuring and forecasting turbulence conditions along a designated propagation path.





DELTA-Wx provides a Machine Learning solution to Surface Level turbulence compatible with SHaRE Scaling Codes

Image and Feature Data	Initial positions, subpixel locations over full image sequence, differential jitter measurements, optional raw images
C_n^2 Profile	Turbulence statistics including C_n^2 profiles, Rytov number, and r_0, isoplanatic angle, and wind speed
Weather Station	Commercial weather station with integrated data acquisition, plotting, and machine learning algorithm.
Scene & Additional Information	Range, IFOV (~2μrad), embedded camera information (gain, shutter, etc.), wind speed estimates, timestamps, etc.
System Hardware	4" aperture telescope, tripod, camera, and electronics ~50 pounds in 4' footprint. ~100 W max power. Network connectivity options. Modular target board and cases.



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