Solar Radiation, Low-Level Cloud, and Boundary Layer Characteristics over Eastern North Carolina

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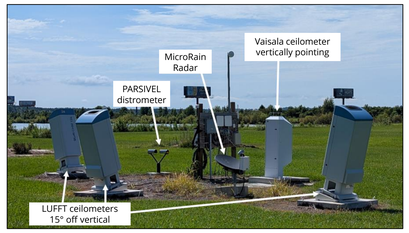
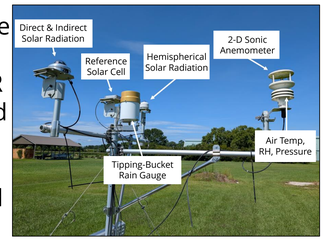
Motivation

The sizes, persistence, and types of clouds impact downward solar and infrared radiation with implications for local temperatures, solar energy production, aviation, and remote sensing. Low cloud formation and dissipation are strongly influenced by the degree of mixing in atmospheric boundary layer. Key controls on the boundary layer include diurnal cycles and air mass changes. We assess the superposition of these controls to better understand the natural variability of low clouds in various weather conditions. Solar energy photovoltaic (PV) output is ~linear to the amount of solar radiation reaching the surface. The magnitude and variability of GHI are crucial metrics for solar energy production.

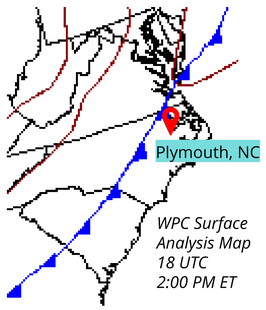
Data & Methods

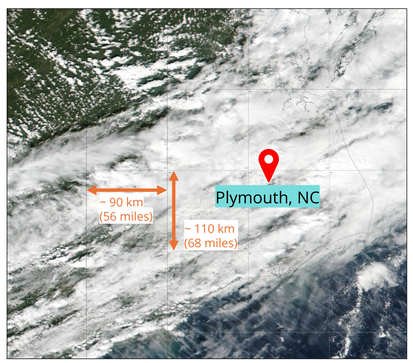
We use data from NCSU's Eastern Carolina Atmospheric Observing Site in Plymouth, North Carolina (59 miles, 95 km from the Atlantic coast) to examine joint variations in meteorological variables, including Global Hemispheric Irradiance (GHI), temperature, dewpoint, precipitation, wind direction, and LiDAR ceilometer profiles of aerosol and cloud particles in the boundary layer. Image processing techniques are used to identify clouds and stable versus mixed conditions from backscatter and LDR. In our time-series observations, cold frontal passage is identified primarily by rapid drops in dewpoint.





Cold Front Example: 2025-10-08 at 1:30 PM ET

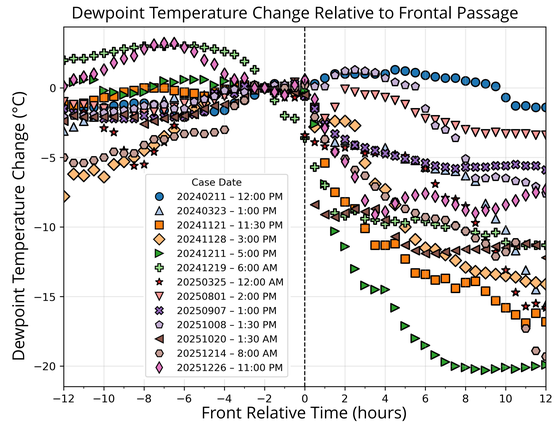


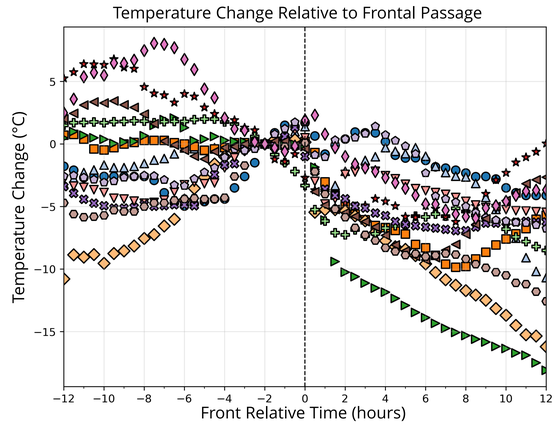


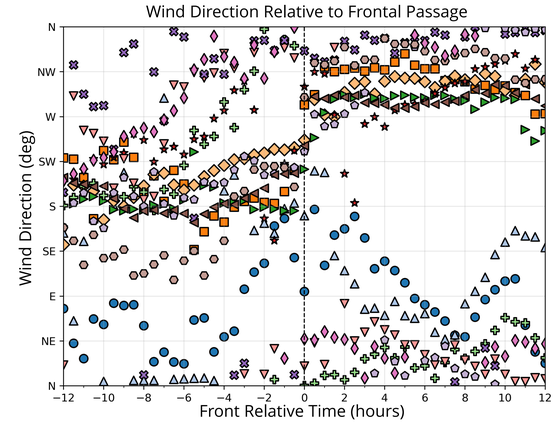
NASA Worldview visible satellite image from 2025-10-08 2:47 PM local time. High-altitude cirrus and lower cumulus clouds.

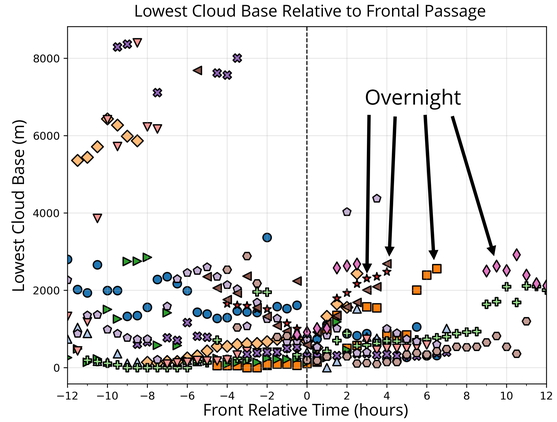
The orange vertical line indicates the local time of the frontal passage. The gray vertical line at 18:47 UTC indicates the time of the visible satellite image. The horizontal yellow line in all GHI time series plots indicates a solar radiation of 200 W/m².

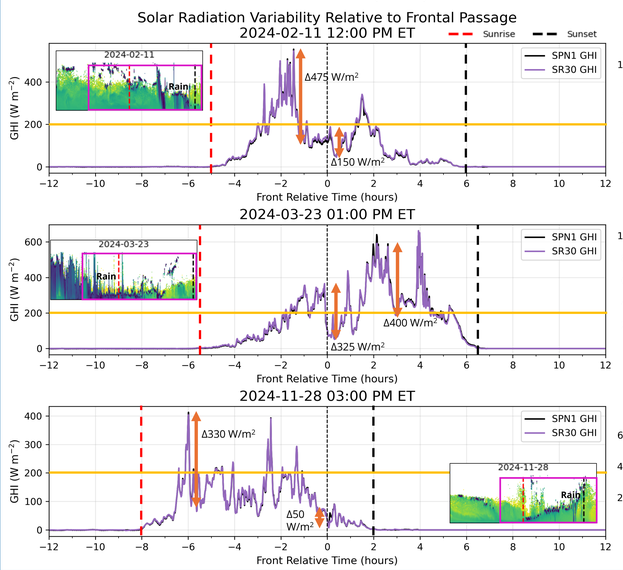
Front Relative Characteristics

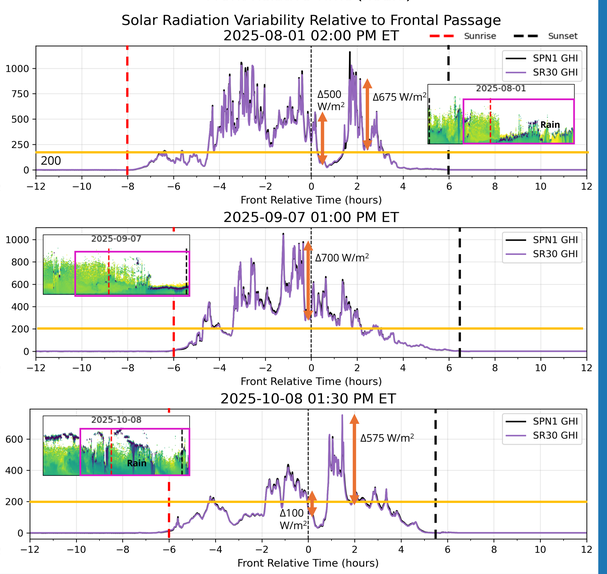












Summary & Future Work

During daytime intermittent cloudiness, the solar irradiance can vary rapidly, often by more than several hundred W/m² in less than 5 minutes. Depending on the sizes and lifetimes of individual clouds, variations from near 700 W/m² to a few 100 W/m² can occur at hourly and subhourly time scales. Daytime periods with precipitation typically have irradiance values of 50 W/m² or less. Neither wind direction nor cloud base heights consistently correspond to the idealized schematics of cold fronts in many textbooks. The diurnal cycle appears to have a stronger influence on low cloud bases than air mass changes. In the future, we will analyze more examples and combine these data with all-sky camera images to define the phase space of low cloud changes by weather condition, diurnal cycle, and season.

Acknowledgements

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