An Opportunity to Develop a State-of-the-Art Tethered Lifting System (TLS)

Michael L. Jensen, Rod G. Frehlich, and Ben B. Balsley
CIRES Atmospheric Dynamics and Remote Sensing

Overview

The CIRES Tethered Lifting System (TLS) has been under continuous development and use now for over a decade. The TLS comprises a kite or aerodynamic blimp that lofts a suite of instruments up to 2-3 km and can produce high-resolution profiles of winds, temperatures, humidity, turbulence properties, and trace gases rapidly and accurately. There is literally no other technique that can obtain such detailed information over a single location and over such a wide altitude range on a relatively continuous basis. As a result, TLS results are becoming well-known throughout the global atmospheric community. Specifically, CIRES researchers have "flown" the TLS in the U.S. (Kansas, Oklahoma, Texas, Washington D.C., and Hawaii), Nova Scotia, Newfoundland, Azores, France, the Amazon Basin, Australia, Greenland, the Arctic Polar Region, as well as aboard a NOAA ship in the Pacific.

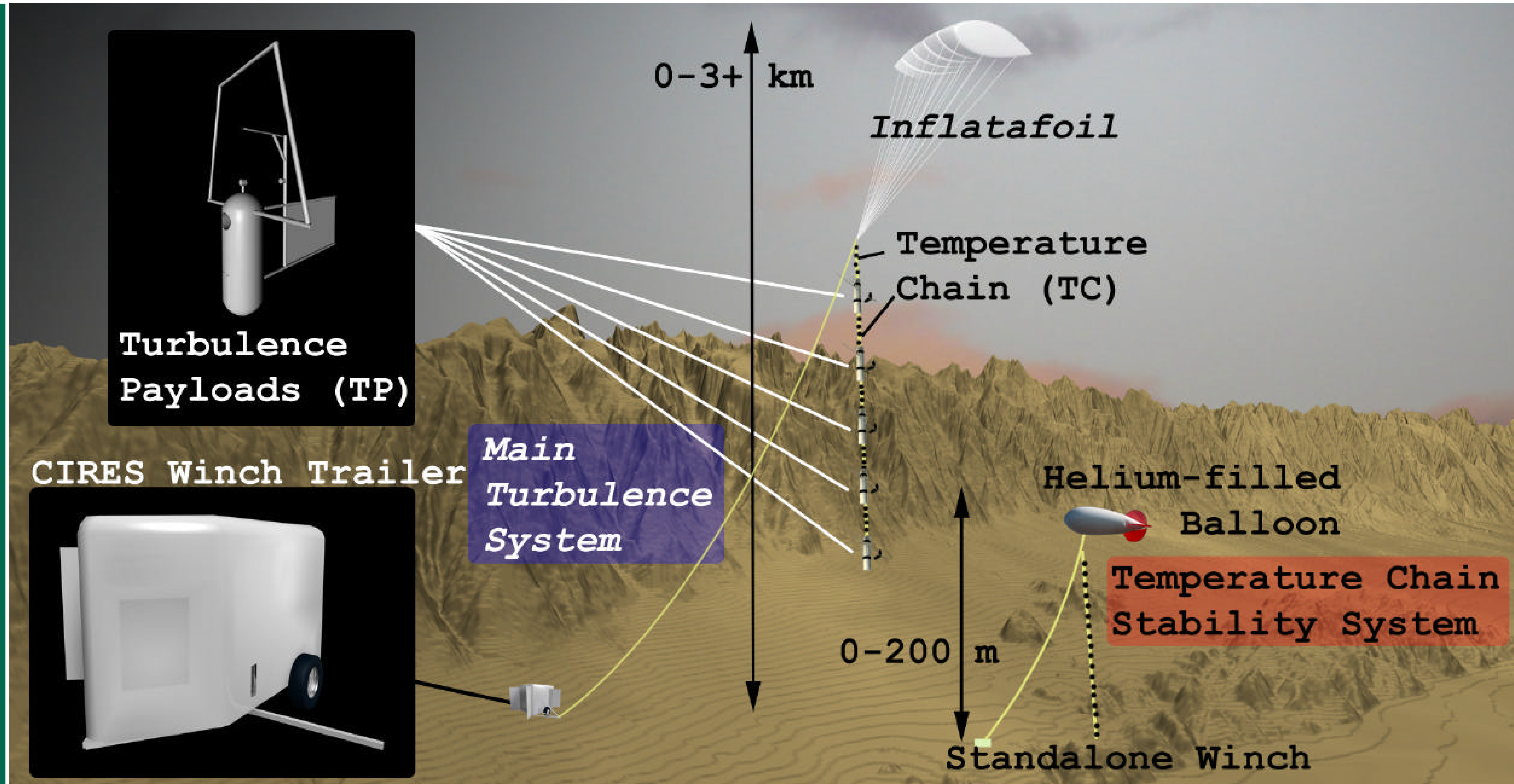
Accomplishments

Using the combined funds from a DoD Defense University Research Instrumentation Program (DURIP) grant (supporting equipment and parts expenses) and the CIRES IRP (supporting salaries for system development and design) we have been able to completely redesign the CIRES TLS from the ground up, literally!

While we continue to expend DURIP funds to construct and build the improved CIRES TLS, IRP funds have been instrumental in supporting the redesign of all the fundamental components of the system: the winching system, lifting platform, and instruments. Improvements include (1) design of a new hybrid lifting device, dubbed the Inflatafoil which combines the best features of our parafoil kites and helium-filled balloons in a single platform, (2) a self-contained state-of-the-art trailer-winch system allowing for more efficient field operations and profiling capabilities, (3) extension of our fine-wire turbulence sensor instrument's capabilities to include continuous sampling at higher data rates and additional support sensors including on-board sonic wind calibration, and (4) the design of a string of temperature sensors (Temperature Chain) which will allow us to make never-before possible continuous observations of nocturnal boundary layer stability and boundary layer height variability.

Impact

The improvements we're making to the CIRES TLS have already generated sufficient interest from the atmospheric research community that we are hopeful for funding to participate in the Turbulence in Rotors Experiment (T-Rex) taking place in California next spring, as well as genuine interest from the wind-energy community, specifically the nearby National Wind Technology Center (NWTC).



The TLS Main Turbulence System

Incorporating a newly designed trailer-mounted winch, hybrid lifting platform, improved turbulence and basic meteorology instruments, and upgraded telemetry and ground station hardware, the TLS Main Turbulence System is capable of continuous, high-frequency turbulence measurements from multiple packages from the surface to over 3 km.

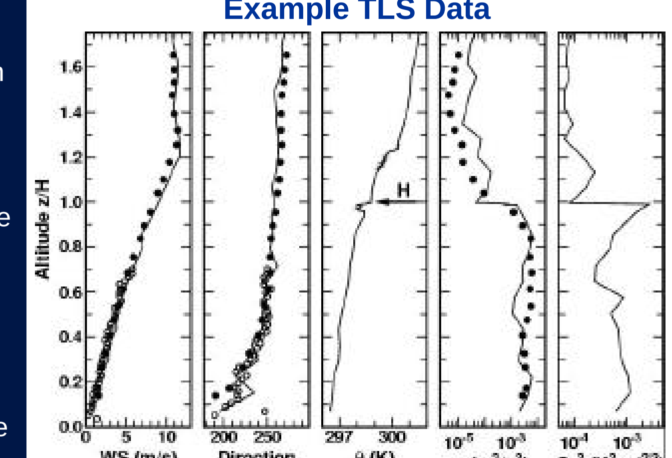
The 20-foot trailer houses the 5 hp, electric TLS winch, telemetry ground station (high-bandwidth radio modems and differential GPS base station), instrument storage, workbench, and helium tanks to make field operations more efficient and cost effective. The new winch is rack mounted and can be secured to the TLS trailer for normal operation or removed and shipped in a standalone configuration for use in remote locations beyond the reach of the towed trailer.

Preliminary design of a new hybrid lifting platform has also been completed. This platform, dubbed the Inflatafoil, incorporates the best qualities of the parafoil kites and helium-filled blimp-shaped balloons that the CIRES TLS group has used for over a decade. The Inflatafoil offers buoyant lift, in addition to the dynamic lift generated by the wind, while limiting overall lift forces by passively reducing its angle of attack relative to the wind.

The Turbulence Payloads' (TP) capabilities have been expanded to include continuous sampling (old version sampled 300 seconds then wrote data for 9 seconds), higher data sampling rates (2 kHz vs. 200 Hz), improved on-board wind (1-D sonic anemometer) and temperature (shielded and aspirated) calibration measurements, and GPS time synchronization and geolocation in a lighter weight package that consumes less power.

The Basic Meteorological Payload (BMP) has been enhanced with the addition of a 3-D sonic anemometer for wind measurement, differential GPS for precise altitude and position determination, improved attitude sensors, and real-time high-speed telemetry to allow for interactive positioning of the entire TLS sensor suite for optimal scientific benefit.

Example TLS Data



Comparison plots of TLS data (solid lines), mini-sodar data (open circles), and Doppler lidar data (solid circles) from the Pentagon Shield experiment in Washington, DC. Data were obtained using a preliminary version of the improved TP, demonstrating the utility of the TLS system for in-situ verification of remote sensing data.

Temperature Chain Stability System

The Temperature Chain Stability System is an experimental design aimed to improve the determination of boundary layer stability.

The TLS standalone winch automatically and continuously raises and lowers a high-density string of temperature sensors, allowing for intercalibration of the neighboring sensors and therefore the high differential accuracy required to sense shallow temperature gradients over relatively small distances.

The ability to accurately measure stability, especially in near-neutral conditions, is vital to understanding nocturnal boundary layer dynamics, and specifically transport and diffusion (T&D) of chemical species, moisture, and heat between the surface, boundary layer, and free atmosphere.