University of Notre Dame Hazard Property Tower Data

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1.0 Data Set Description

The University of Notre Dame (UND) employed a meteorological tower at the Hazard Property (HP) during the Sundowner Winds Experiment (SWEX) campaign that lasted from April 1 to May 15, 2022. The HP site was located on the south/lee side of the Santa Ynez mountains. The tower data taken in a continuous sense from the start to the end of the experimental period contains information three-dimensional wind velocity, sonic temperature, temperature, relative humidity, and incoming and outgoing long- and short-wave radiation at various heights above ground level.

Data version: 0.0 (submitted September 19, 2023, last updated May 15, 2022)
Data status: preliminary data
Time period covered by data: These periods are summarized in Table 1 below, which was made based on the 15-minunte averaged data. The raw data may have outliers and bad data indicators that the user (at this time) needs to remove him/herself. In later products, the "despiked" data will be offered, which has more rigorous quality control. The delay in data from the 6-meter temperature and relative humidity sensor (referred to as the T/RH probe throughout) is due to a faulty probe, which the UND team replaced on April 1, 2022.

Table 1: Data availability from each of the tower instrumentation segments.

Instrument	**Height AGL**		
	2 m	**6 m**	**10 m**
Sonic anemometer	March 28 – May 15	March 28 – May 15	March 28 – May 15
T/RH probe	March 28 – May 15	April 2 – May 15	March 28 – May 15
Net radiometer	March 29 – May 15		

Physical location of the measurement platform: 34.518807°, -120.079295°, 480 meters above MSL. Below in Photo 1 is a picture of the Hazard Property meteorological tower. The HP site is located on the south side of the Santa Ynez Mountains, with the Pacific Coast located to the south.

Photo 1: The location of the tower at HP. Sonic anemometers and temperature relative humidity probes are pictured at 2, 6, and 10 meters, along with a net radiometer at 2 meters above ground level.

Data frequency: Table 1 below summarizes the data acquisition rates of each instrument on the meteorological tower. Details on the manufacturer and number of instruments at each height above ground level are provided in Section 2 below.

Table 2: Data acquisition rates for the tower instruments.

Data source	Data frequency
Sonic anemometer	14 Hz
temperature/relative humidity probe	1 Hz
Net radiometer	1 Hz

Data source: Meteorological tower, University of Notre Dame
Web address references: Notre Dame SWEX information, SWEX Field Catalog, National Science Foundation Award
Data set restrictions: none

2.0 Instrument Description

The HP meteorological tower features three different instruments at various heights from Tables 1. Below in the subsections are descriptions of the instruments, including model and manufacturer and a brief theory of operation.

2.1 Sonic Anemometer

The R.M. Young Model 8100 ultrasonic anemometer measures the three-dimensional wind velocity vector in a small volume, which acts effectively as a point measurement, based on the travel time of acoustic pulses in air. The pulses are sent out by three pairs of ultrasonic transducers, and where the pulses cross paths is the measurement volume. From one pair of transducers (1 and 2) separated by distance d, if the transit times from 1 to 2 t_1 and 2 to 1 t_2 are measured, the velocity along the path of transit $u_{\parallel}$ is found by

$$u_{\parallel} = \frac{d}{2}\left(\frac{1}{t_1} - \frac{1}{t_2}\right).$$

Along three axes, or transit paths, the three-dimensional wind vector is calculated. The anemometer also measures the speed of sound, and from this derives a temperature surrogate called the sonic temperature, whose fast (14 samples per second) fluctuations allow for accurate calculations of turbulence statistics, despite the mean values not always indicating of the true air temperature. In fact, sonic temperature resembles virtual temperature more than the air temperature because it considers the effects of moisture on the speed of sound through the atmosphere over simply dry air.

2.2 Temperature and Relative Humidity Sensor

The Campbell Scientific EE181 Air Temperature and Relative Humidity Sensor (referred to throughout as the T/RH probe) measures air temperature using a thermistor encased in an aluminum housing; this probe is additionally placed in a radiation shield to protect against false readings due to warming from solar radiation throughout the day. The temperature sensor is a Pt1000 while the humidity sensor is an HC101. Note that the probe at 6 meters above ground level on the tower was faulty, and the UND team substituted it for a Campbell HC2S3 sensor, which is a slightly older model but operates similarly to the previous probe.

2.3 Net Radiometer

The Campbell Scientific CNR4 net radiometer consists of two pairs of instruments, pointed in opposite directions vertically, one pair of pyranometers and another pair of pyrgeometers. The former pair measures incoming and outgoing short-wave solar radiation, while the latter measures incoming and outgoing long-wave radiation. For the pyranometer (pyrgeometer), the simple equation to convert from measured voltage V to calculated irradiance E is

$$E = \frac{V}{C}(+\sigma T^4),$$

where C is a calibration constant, $\sigma = 5.67(10)^{-8}\ \mathrm{Wm^{-2}K^{-4}}$ is the Stefan-Boltzmann constant, and T is the temperature of the pyrgeometer, which in the instrument is measured by a thermistor and Pt-100 sensor. With these measurements, a calculation of albedo a using the upper u and lower l pyranometer irradiances E_i can be made according to the following equation:

$$a = \frac{E_l}{E_u}.$$

Net outgoing radiation R_n is calculated as

$$R_n = \sum E_u - \sum E_l,$$

where the summation is over both the pyranometer and pyrgeometer values for E_i. Variables such as the albedo a and net outgoing radiation R_n will be available in the next release of this dataset.

3.0 Data Collection and Processing

Data was taken in a continuous sense between the dates specific in Table 1 above and at the sampling rates described in Table 2. Although the earliest data acquisition started March 28, 2022, trustworthy data begins on April 2 for the 6-meter T/RH probe, which is a consequence of a faulty probe that was replaced on April 1.

The UND team employed a Campbell Scientific CR3000 data logger to manage the data storage for all the instruments on the tower. The standard data logger program failed to execute, both with single-end and differential voltage inputs from the instruments into the logger. The fast response data acquisition rate for the sonic anemometers of 20 hertz created an error in the program. For this reason, the team changed the rate to the highest rate the Campbell Scientific CR3000 data logger program could handle – 14 Hz. Despite these challenges, the slow response data was unaffected by these data logger issues; the data logger captured the T/RH and net radiometer data at 1 Hz.

From the raw datalogger files, UND has split the data into daily files, which are further separated into fast (sonic anemometer) and slow response (T/RH and net radiometer) data. Similarly, 15-minute averaged data has been generated from the original data points, with some mild quality control ("despiking" or removing outliers).

Products to come in the next data release include spectral quantities, estimates of dissipation rate via the eddy covariance method and the inertial dissipation methods, Monin-Obukhov parameters, friction velocity, Reynolds stress, and many others standard for atmospheric analysis.

4.0 Data Format

The first file type to review is the `Daily.txt` files, which have all the fast response data (three-dimensional wind vector components and sonic temperature) written in them. These files have the following naming convention:

`YYYY-MM-DD_HP_14Hz_ZmDaily.txt`,

where `YYYY` is the year (2022 for this entire dataset), `MM` is the 2-digit month (01-12), `DD` is the 2-digit day (01-31), `HP` indicates data from Hazard Property, `14Hz` indicates the sampling rate, `Zm` is the height of the measurement (2, 6, or 10 meters), and `Daily` indicates that this is a daily file. The structure of each line of the comma-delimited `Daily.txt` file is

`YYYY,M,D,H,m,SS.ss,u,v,w,T`,

where `YYYY` is the year, `M` is the 1- or 2-digit month, `D` is the 1- or 2-digit day, `H` is the 1-2 digit hour (0-23 hours), `m` is the 1- to 2-digit minute, `SS.ss` is the decimal second, `u` is the easterly wind component (m/s), `v` is the northerly wind component (m/s), `w` is the wind from below (m/s), and `T` is the sonic temperature (^{O}C).

The second file type uploaded is the `DailyTRH.txt` files, which have data from all the slow response instruments on the tower (T/RH probes and net radiometer). Note that unlike the `Daily.txt` files, these files are not segregated based on instrument height – all the data is together in one daily file. The file name convention is as follows:

`YYYY-MM-DD_HP_1Hz_DailyTRH.txt`

where `YYYY` is the year (2022 for this entire dataset), `MM` is the 2-digit month (01-12), `DD` is the 2-digit day (01-31), `HP` indicates data from Hazard Property, `1Hz` indicates the sampling rate, and `DailyTRH` indicates that this is a daily file with the T/RH (and net radiometer) instrument data. The structure of each line of the comma-delimited `DailyTRH.txt` file is

`YYYY,M,D,H,m,SS,T2,RH2,T6,RH6,T10,RH10,SWUP,SWDN,LWUP,LWDN`;

where `YYYY` is the year (2022), `M` is the 1-or 2-digit month (1-12), `D` is the 1-or 2-digit day (1-31), `H` is the 1- or 2-digit hour (0-23), `m` is the 1 or 2-digit minute (0-59), `SS` is the 1- or 2-digit second (0-59), `Ti` is the i-meter temperature (^{O}C), `RHi` is the percentage relative humidity at i meters, `SWUP` is upwelling short-wave radiation (W/m^2), `SWDN` is downwelling short-wave radiation (W/m^2), `LWUP` is upwelling long-wave radiation (W/m^2), and `LWDN` is downwelling long-wave radiation (W/m^2).

The 15-minute averaged data is also separated into slow and fast response datasets. The 15-minute averaged fast response data has the following naming convention:

HPZm.txt,

where Z is the height of the measurements in meters. Inside this 15-minute averaged file are the following variables:

YYYY M D H m u v w T,

where YYYY is the year (2022), M is the month (1-12), D is the day (1-31), H is the hour (0-23), m is the minute (0, 15, 30, 45), u is the 15-minute averaged easterly wind (m/s), v is the 15-minute averaged northerly wind (m/s), w is the 15-minute averaged upward wind (m/s), and T is the 15-minute averaged sonic temperature (^{O}C).

The slow response 15-minute averaged data file has a similar naming convention:

HP.txt,

and possesses the following format:

YYYY M D H m T2 RH2 T6 RH6 T10 RH10 SWUP SWDN LWUP LWDN.

The variables in the file remain the same as for the DailyTRH.txt file, except now quantities are 15-minute averaged ones.

5.0 Data Remarks

From the daily files and 15-minute averaged files, it seems that the 6-meter T/RH probe was misbehaving before April 2, 2022. Spurious values of negative relative humidity and temperature values that do not agree with the other two levels' readings indicated that the probe needed to be replaced; this was done so late April 1, 2022. This inaccuracy in measurement can be seen in Figure 1 below. Additionally, the net radiometer long wave downwelling radiation may be faulty – it does not return to zero but rather continues to drift further from it with time. This may be an instrument error with that specific pyrgeometer.

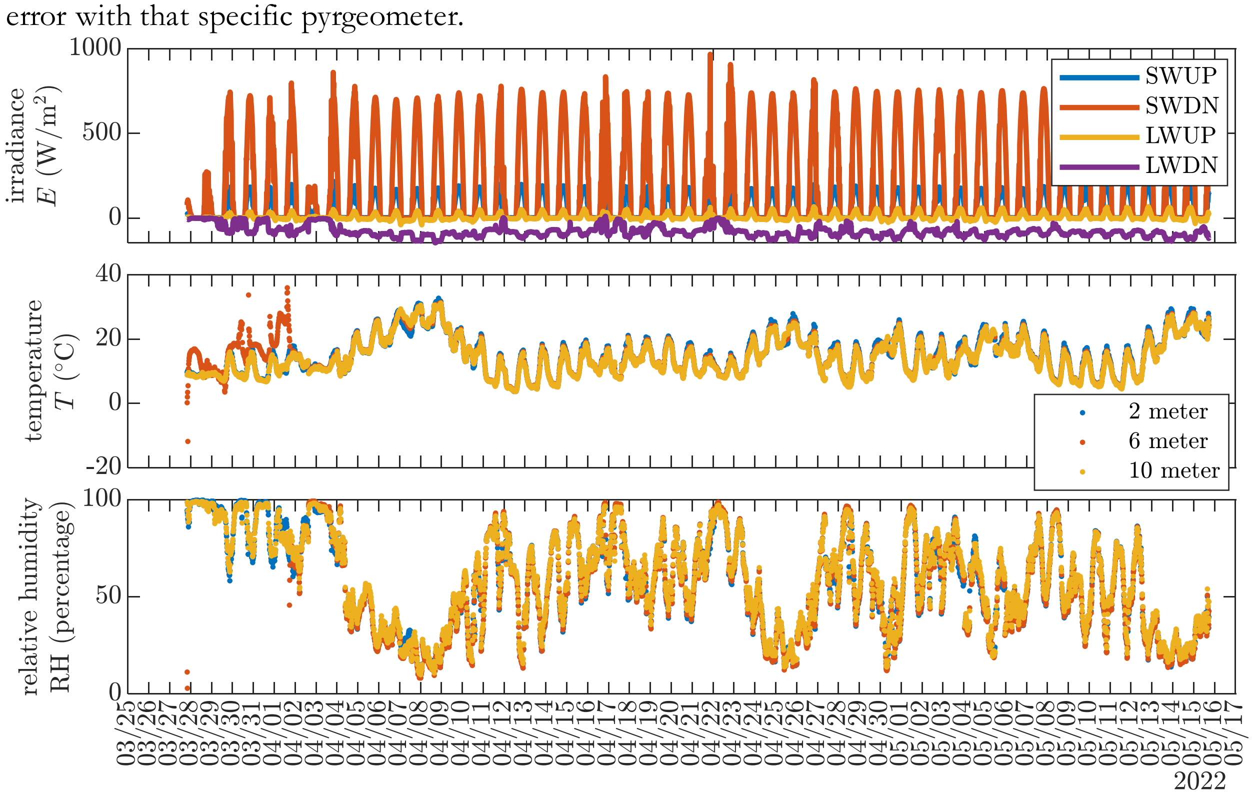

Figure 1: A plot of the 15-minute averaged slow response data from the net radiometer and T/RH probes. Note the untrustworthy 6-meter temperature and relative humidity data until midway

through April 1, 2022. Also note the drift in the long wave downwelling radiation on the first subplot.

Lastly, the 10-meter sonic anemometer data is offset from the other two sonic readings, potentially by a constant value due to miscalibration; this is currently being explored with the hopes of recovering that 10-meter data. Figure 2 displays the 15-minute averaged fast response data from the sonic anemometer for the whole experimental period, highlighting the offset that the 10-meter sonic reading has.

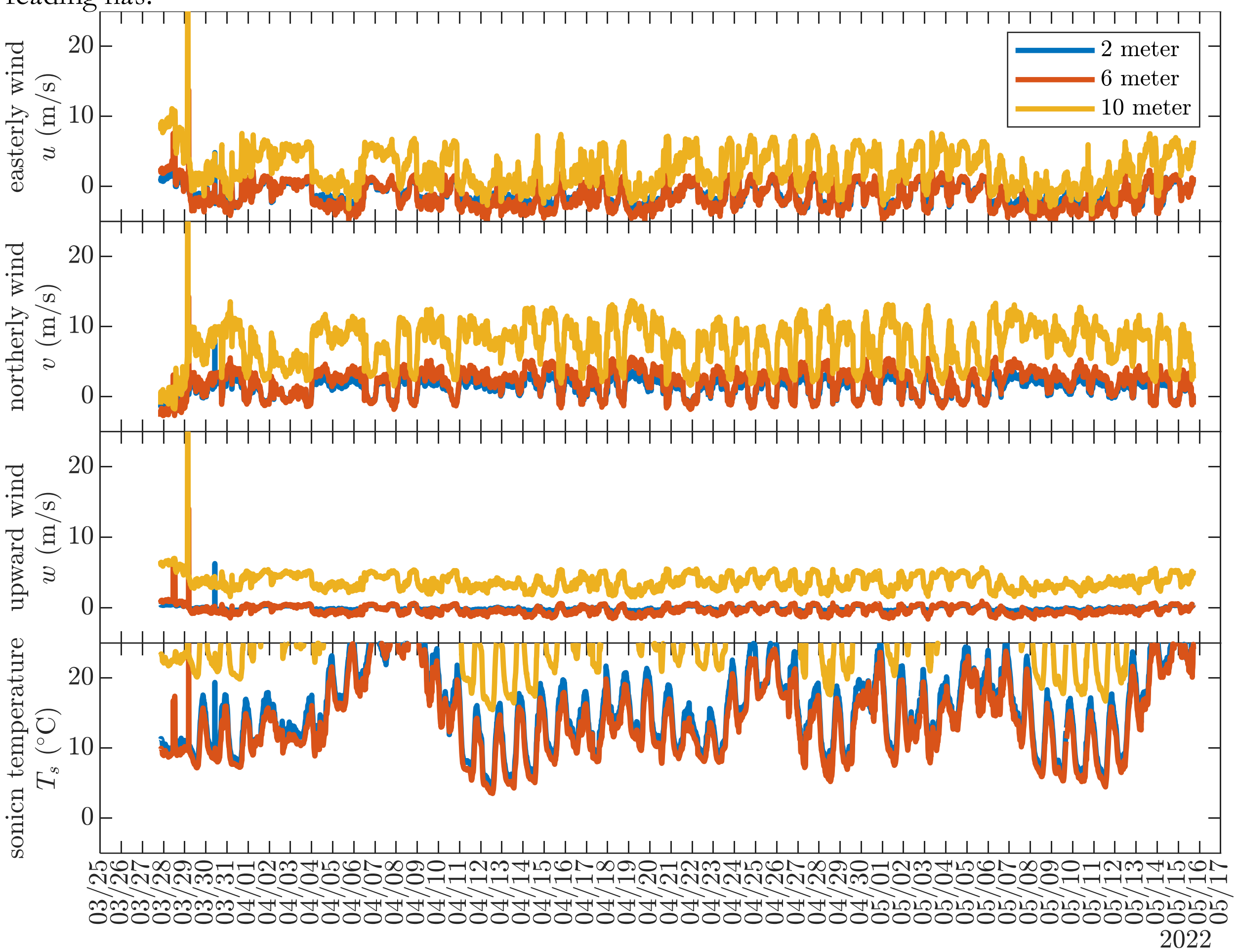

Figure 2: A plot of the 15-minute averaged sonic anemometer data over the entire recording period. The offset between 2- and 6-meter wind and temperature and the 10-meter readings is too large to be physical.

6.0 References

1. R.M. Young Meteorological Instruments, "Instructions: Ultrasonic Anemometer Model 81000."
2. Applied Technologies, Inc., "Operator's Manual for a Three Axis Sonic Anemometer/Thermometer" (Revision G).
3. Campbell Scientific, Inc., "EE181 Temperature and Relative Humidity Probe" (2021).
4. Campbell Scientific Inc., "CNR4 Net Radiometer" (2021).

This dataset was used by Griffin Modjeski on his poster for the IX International Symposium on Stratified Flows (ISSF), which took place at the University of Cambridge from August 29 – September 1, 2022.