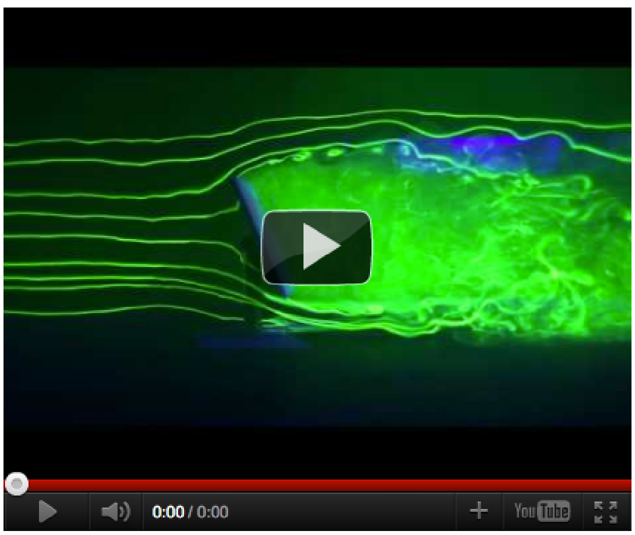
RE<C: Surface Level Wind Data Collection

Overview

Our design for a lightweight heliostat reflector and frame is potentially susceptible to wind damage and deflection. As the flow visualization and CFD (Computational Fluid Dynamics) modelling show, the effects of wind are more complicated than pure static loads from steady wind. Air currents flowing around heliostats form turbulence and vortices which can lead to reflector flutter.



Video: Heliostat Vortex Shedding

We needed high-frequency sampled wind data to gain a better understanding of the wind characteristics and improve our heliostat design. We discovered that wind data (speed, direction, and elevation) at a resolution of less than one second is not readily available.

To gather this data, we set up an array of anemometers[1] to measure the wind speed and direction for a period of one month at a location in Tracy, CA, known for gusty wind conditions.

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[1] We used an array of R.M. Young 3-Axis Ultasonic Anemometers: http://www.youngusa.com/products/6/45.html

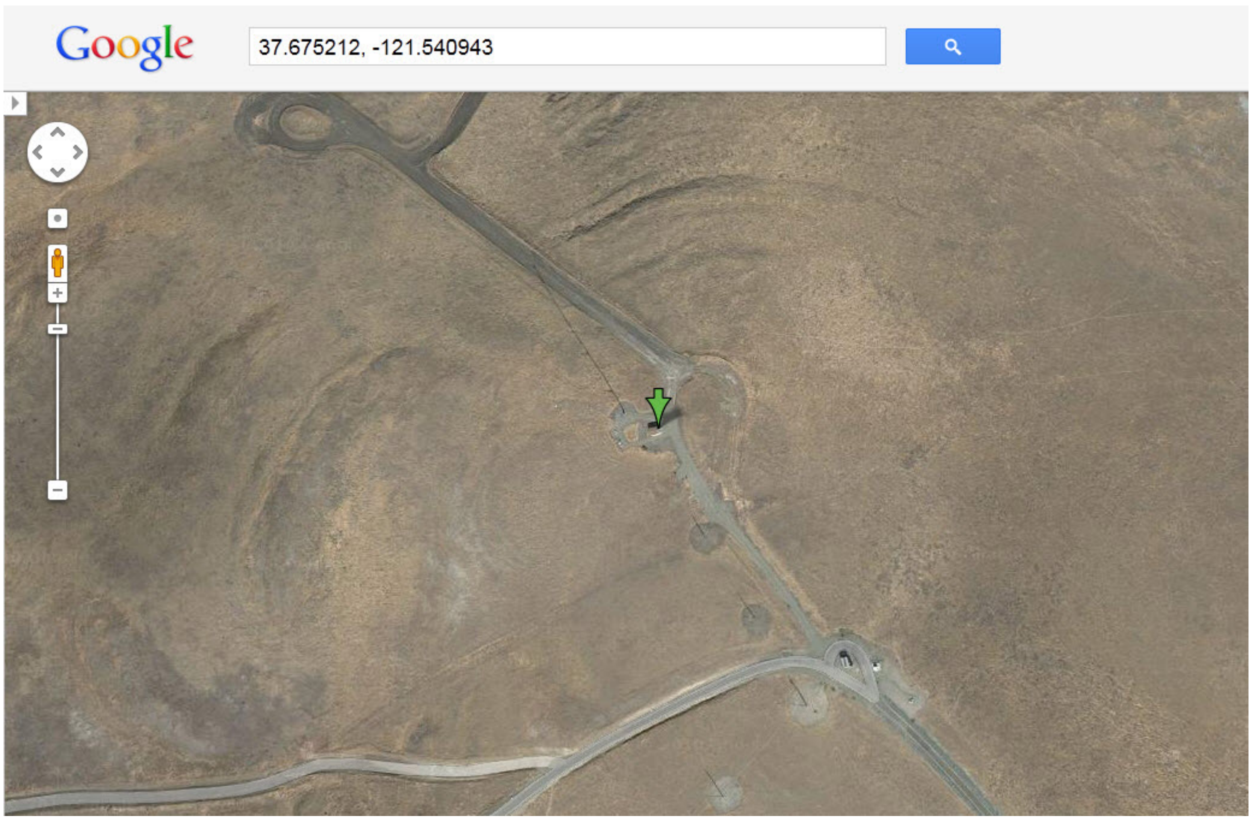
We sampled wind data at 7.6 Hz, approximately one sample every 0.13 seconds.

We are providing this recorded data for analysis to anyone who may be interested. We hope it assists heliostat designers and others to gain insights into wind phenomena close to ground.

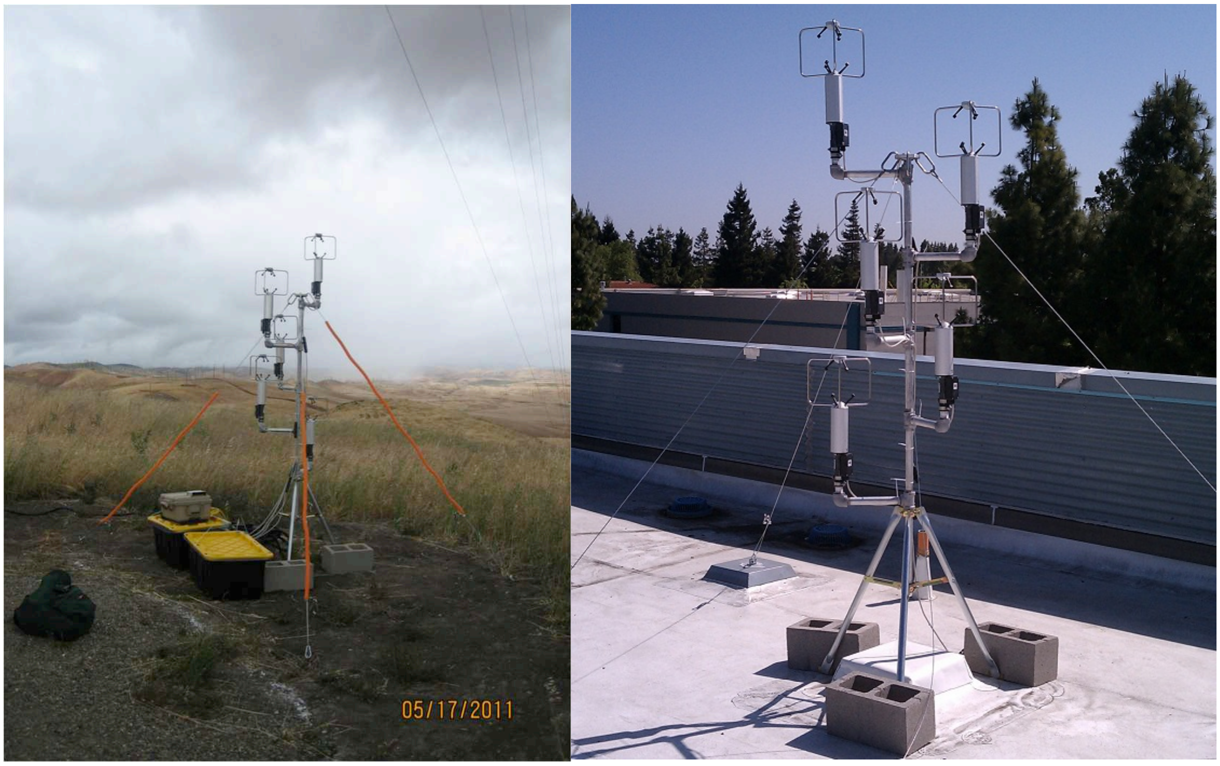
Data Collection Setup

Data sampling was taken close to Tracy, CA at 37.675212, -121.540943. We chose this spot because it's relatively flat and windy. We collected data between May and June, 2011 using the following equipment:

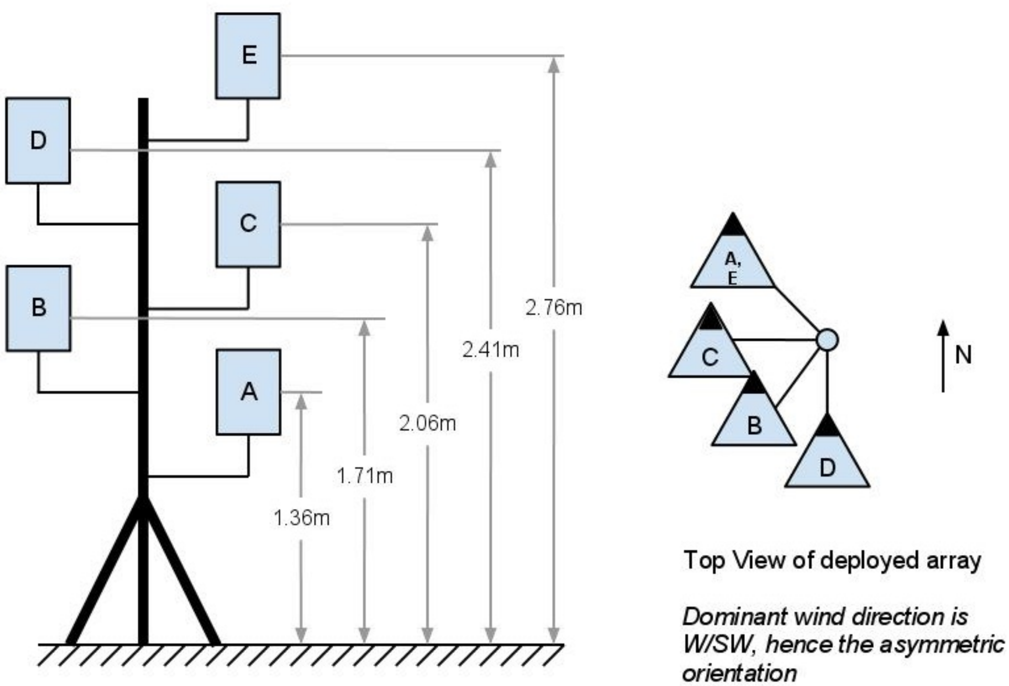
- **Anemometers:** RM Young 81000V, 3-axis ultrasonic anemometers
- **Sampling Rate:** 7.6 Hz
- **Data Acquisition System:** National Instruments cRio (hardware) and Labview (software)



Aerial view of the wind data site



Left: Anemometer array deployed at Tracy site to record atmospheric wind conditions. Right: Similar anemometer array on Google's rooftop lab



Physical setup of anemometer array

Recorded Data Format

Data was recorded in text files (.txt) which contain ASCII data in a CSV format. The data is saved in the following order with no header line in the file:

date,time,skip1,skip2,box_temp,A,spd_A,azi_A,ele_A,B,spd_B,azi_B,ele_B,C,spd_C,azi_C,ele_C,D,spd_D,azi_D,ele_D,E,spd_E,azi_E,ele_E

Values in the data files have the following formats:

- **date:** Date stamp of sample (MM/DD/YYYY)
- **time:** Timestamp of sample (HH:MM:SS.FFF)
- **skip1:** Extra comma
- **skip2:** Extra comma
- **box_temp:** Temperature of Data Acquisition box (deg F)
- **X:** Character, A, B, C, D, E (identifying the start of an anemometer's reported data, based on the character)
- **spd_X:** Wind velocity magnitude (m/s) measured at anemometer X
- **azi_X:** Azimuth direction (deg), measured at anemometer X, relative to North (0 deg)
- **ele_X:** Elevation angle (deg), measured at anemometer X, relative to horizontal (0 is horizontal positive is towards the sky)

The following is a sample of a data file for May 17th, 2011:

```
05/17/2011,12:23:51.922,,,66.2,A,3.87,154.5,-5.9,B,3.50,136.7,-6.2,C,3.78,143.3,0.9,D,4.18,139.5,7.1,E,4.03,145.6,6.9
05/17/2011,12:23:52.053,,,66.2,A,3.76,151.2,-9.4,B,2.63,134.9,18.6,C,3.36,137.1,7.2,D,4.05,144.3,4.5,E,3.98,145.7,1.0
05/17/2011,12:23:52.184,,,66.2,A,2.97,144.0,6.9,B,2.91,147.3,12.4,C,3.14,138.6,11.4,D,4.00,147.4,10.2,E,4.71,145.5,-2.2
```

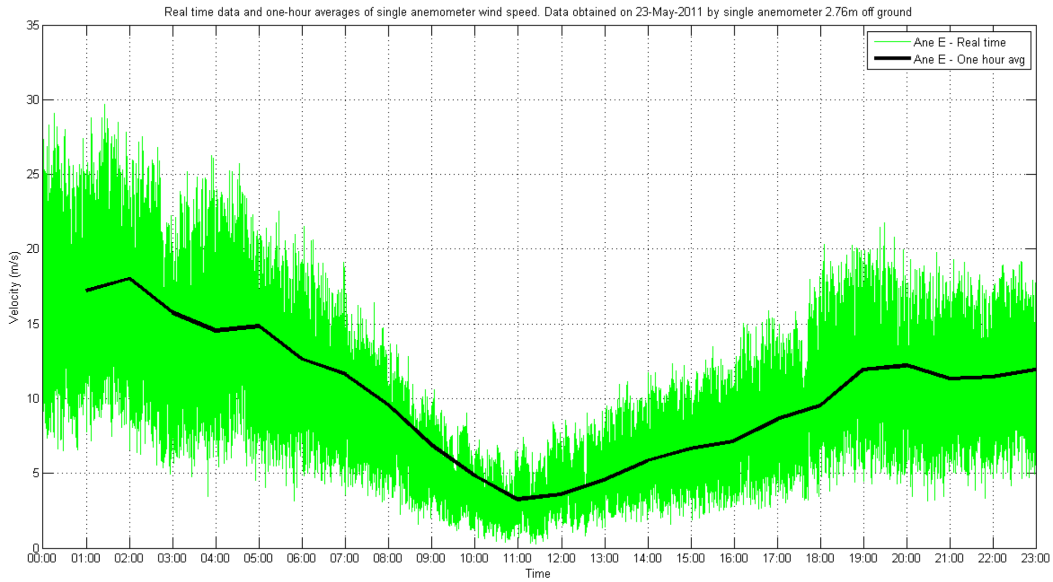
Wind data sample

Raw Data Files

All raw wind data files are available for download from Google. Each file contains a day's worth of data. Files may be obtained by visiting: http://code.google.com/p/google-rec-csp/downloads/list

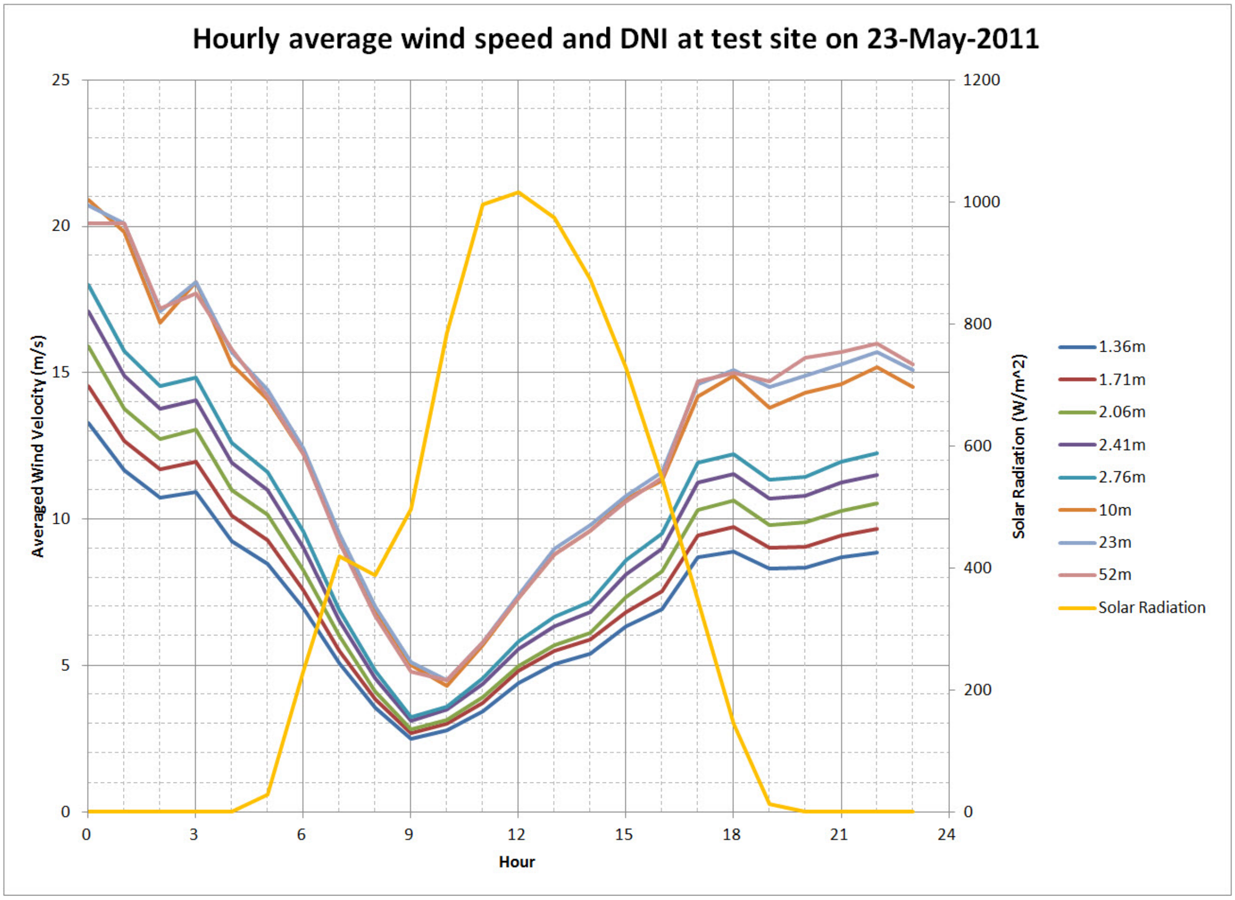
Wind Data Analysis

The following graphs show a few of the analyses we performed upon the measured wind speed data from May 23, 2011. Comparing one hour wind speed averages (black) with our data samples for wind speed at 7.6 Hz (green), we see the necessity for tracking actual wind speed data instead of relying on averages. The average hourly 15 mph (6.7 m/s) wind speed measured at 5 a.m. doesn't reveal that wind speeds were rapidly fluctuating between 5 mph (2.2 m/s) and 20 mph (8.9 m/s) during that time.



Sampled data at 7.6 hz (Green) vs 1-hour averages for anemometer E (black)

In another analysis, we compared the level of solar radiation throughout the day to the recorded wind speed averages. This also allowed us to compare the near-surface wind speed data we collected with more standardly reported wind data at 10m, 25m, and 52m. We obtained solar radiation data and the additional wind speed data from the Lawrence Livermore National Laboratory meteorological station nearby. The analysis revealed that for our location, wind speed was usually lowest during times of peak solar radiation.



Hourly wind speed averages and incoming solar radiation

Conclusions

Surface-level wind characteristics are important to the design of systems which are exposed to the open environment. Wind speed is a function of location, altitude, time of day and season. Ground constructions must be designed to accommodate changes in wind speed due to wind gusts, turbulence and vortices.

For heliostat designs, it's particularly important to determine how daily patterns of wind coincide with solar availability. From the limited data we have on the site, we can see that the site we chose was quiet during the day, which bodes well for keeping reflected light on target. This site was windiest at night, so it would be important to program the heliostat to stow the reflector in a position that prevents wind damage while not in operation. Wind characteristics in other sites may vary, so for the most cost-effective solution, one should balance the cost of wind mitigation strategies versus the potential lost solar energy due to wind deflection and damage.

We hope that making this high-sample-rate wind data available to the public will prove useful for analysis and future designs, providing designers with insights into wind phenomena close to the ground.