Utah State University

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Sonic Anemometer Calibrations

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About my project

- Went through records to find sonic anemometer installation date ranges.
- Downloaded data off of the Atmospheric Radiation Measurement (ARM) website for Eddy Correlation Flux Measurement systems (ECOR), Surface Meteorological Observation systems (SMOS), and Surface Meteorological Instrumentations (MET) located in the Southern Great Plains (SPG).
- Dates for data ranged from 6/1/06 to 6/1/10.
- Processed the data and plotted ECOR data with respect to sonic anemometer temperatures using MATLAB. Also plotted SMOS/MET temperatures with respect to sonic anemometer temperatures.
- Edited data and looked for wind and site dependencies.
- Performed linear, second order, and third order polynomial fits for SMOS/MET temperatures vs. ECOR temperatures.
ECOR

- The ECOR provides 30-min measurements of momentum flux, latent heat flux, sensible heat flux, and carbon dioxide flux.
- Fluxes are obtained using the eddy covariance technique which requires vertical and horizontal wind components, air temperature, water vapor density and CO₂ concentration.
- Wind components and air temperature are obtained using the sonic anemometer.
- Water vapor and CO₂ are obtained using an infrared gas analyzer.
**Sonic Anemometer**

Example using a 2D sonic anemometer

- Transducers send high frequency acoustic signals back and forth.
- Using travel time and air properties (from the gas analyzer) the speed of sound is calculated.
- Air temperature is then derived from the speed of sound.
- Wind directions are determined from travel time.
**SMOS and MET**

- SMOS records 30-min air temperature averages.
- SMOS provided data for dates from 6/1/06 to 9/30/09.
- MET records 1-min air temperatures.
- MET provided data for dates from 10/1/09 to 6/1/10.
Wind

- Eddy’s make up wind.
- Bad wind directions are caused by surrounding environment (trees, brush, hills, etc.).
- Don’t know from which direction the wind is coming from.
At high temperatures advection occurs causing a spike in wind elevation.

- Negative elevation angles are caused by high pressure such as from storms.
- Suspect data maybe caused from the sonic anemometer not being properly leveled.
**Standard Deviation of Elevation Angle**

- Spike at high temperatures are caused by eddy’s.
- Delete wind directions to look for wind dependency.
- Most of the good wind directions occur at higher temperatures.
**Wind Direction**

- Good wind directions are determined from the kind of environment the ECOR is installed in.
- Sonic 61 is located at E16, which has good wind directions:
  - 134-269 for pasture
  - 334-360 for ungrazed grass
Standard Deviation of Wind Direction

- Bump is caused by eddy’s and thunder storms in the spring and summer time.
- Just like an optical device, the sonic anemometer has a certain resolution. Any wind smaller than the resolution causes large spikes.
- Large numbers are caused by very light wind.
- Think of a weather vain.
Vertical Wind Component

- Vertical wind component reveals information about the type of terrain present.
- Large numbers may be from trees or light wind.
- Small numbers may be from a smooth terrain or from steady wind.
Sensible Heat Flux

- Flux - the amount that flows through a unit area per unit time.
- Sensible heat - energy transfer caused by a difference in temperatures.
- At lower temperatures there is not much heat transfer.
- At higher temperatures the ground is as hot as the air temperature, so not much flow.
- Bottom of the “bow” are the night time readings.
Latent Heat Flux

- Latent heat - energy transfer due to the phase changes of a substance at the same temperature. Usually water.
- During the day air begins to dry out causing latent heat flux to drop.
- Latent heat flux does not drop as much for greener vegetations or for deep rooted plants, such as E3.
Friction Velocity

- Friction velocity is the momentum of a "piece" of air as it is moved around by wind, is put into units of velocity for convenience.
- Simply put, friction velocity is the physical energy transfer.
- Large friction velocities may be caused by eddy’s in a wooded area.
- Smaller friction velocities are where the wind is more steady.
Wind Speed

- Wind speed is the horizontal wind speed.
- Note how sonic 67 now has a higher wind speed than sonic 62. This is because E21 is a wooded area.
- Looked at wind speed to make sure there was no dependencies on air temperature.
**SMOS/MET temp. vs. ECOR temp.**

- Sonic anemometer does a bad job at very high temperatures and at very low temperatures.
- Note the range where the plot is almost linear (where the sonic anemometer works best).
SMOS/MET temp. vs. ECOR temp.

- Site dependencies can be seen in plots.
- Sonic 63 was split up according to site and analysis was performed for the two different sites.
- Sonic 59 was also split. There was very little data for E16 which led to odd numbers in the linear regression. So we only considered data from E5.
SMOS/MET temp. vs. ECOR temp.

- Sonic 67 had very low temperatures in 2010.
- Tried to find date ranges for the lower tail to help with a better regression.
- Could not isolate the data.
SMOS/MET temp. vs. ECOR temp.

- Performed linear regressions for all sonic anemometers.
- Calibrations come from the slope of the regression.
SMOS/MET temp. vs. ECOR temp.

- Performed second order polynomial fits for all sonic anemometers.
- Note the second order polynomials are a better fit than linear fits.
SMOS/MET temp. vs. ECOR temp.

- Performed third order polynomial fits for all sonic anemometers.
- Note the small differences in 2nd and 3rd order polynomial fits.


**Results**

- Slopes from the linear regressions for each sonic anemometer are used to calibrate the anemometer.
- Before each sonic anemometer was install they were calibrated in a temperature and humidity controlled environment.
- Note the scatter in slopes, which means analysis such as this need to be performed frequently.

<table>
<thead>
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<th>Sonic</th>
<th>Old Calibration</th>
<th>New Calibration</th>
<th>W/O Bad Wind Dir.</th>
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Conclusion

- Sonic anemometer calibrations are used in the calculations for sensible heat flux.
- Without proper calibrations the sensible heat fluxes are either underestimated or overestimated.
- With better calibrations better sensible heat fluxes are calculated.
- The sensible heat fluxes are used in boundary conditions for climate models.
- Therefore, better sensible heat flux calculations will result in better climate models.
- Second order polynomials would be better, but this requires a lot of re-programming of the instruments.
- Improved sonic anemometers are on the market, but it would take at least four to five years to collect and analyze data to see if these anemometers are an improvement.
While looking at site plots, plots at E3 showed a decrease in summer time temperatures.

To see if this was a trend, data from 1996 to 2010 were plotted.

From these plots no trend could be seen.

From this I learned a lot of data is required to make a conclusion.