Meteorological Measurements made during RxCADRE

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Overview

• Instrumentation and Experimental Design
  - Overview of CSU-MAPS

• Data Processing

• Preliminary Results
  - Tower measurements: Fire front micrometeorology
  - Doppler wind lidar measurements

• Summary and Conclusions
NSF sponsored, joint-university (SFSU-SJSU) facility that provides:

- Surface-layer measurements and tropospheric profiling

- Fast deployment using a highly-mobile platform

- Measurements for a range of boundary layer applications
California State University-Mobile Atmospheric Profiling System (CSU-MAPS)

1. 32-m extendable meteorological tower.
2. 2012 Ford F250 4x4 Crew Cab
3. Halo Photonics, Streamline 75 Doppler Lidar
4. Radiometrics, MP3000A Microwave Profiler
5. Vaisala DigiCora MW31 radiosonde system
TowerWorx, MAG-106 steel tower-trailer
- GVW: 8200 lbs
- 32 m maximum height
- deploys with 2-persons, ~30 min
- uses outriggers, no guying
- instruments prewired
CSU-MAPS Tower instrumentation

Up to 6 measurement levels:
- four fixed: 9, 15, 22, 32 m AGL

Sensors:
- HMP45C Temp/RH sensor
- Gill 2-D windsonic anemometer
- CSI CSAT 3-d sonic (two)
- Licor 7500 CO$_2$/H$_2$O analyzer
- CSI CR1000, CR3000 loggers
- Powered by 70 W Solar panel
Experimental Design

[Map showing experimental design with L1G, L2G, and L2F areas. The map includes various markers for tower positions.]

RxCADRE Tower Positions
Legend
- Blue circle: Micromet Tower
- Orange circle: LIDAR
- Green circle: CSU-MAPS
- Red line: Boundaries

Scale: 0 475 950 1,900 Meters
Sounding: 4 Nov 2012

- Potential Temperature (K)
- Water Vapor Mixing Ratio (g kg\(^{-1}\))
- Wind Speed (m s\(^{-1}\))
- Wind Direction (°)

Graphs showing variations in height (m AGL) and different weather parameters over time.
Sounding: 10 Nov 2012

- Potential Temperature (K)
- Water Vapor Mixing Ratio (g kg⁻¹)
- Wind Speed (m s⁻¹)
- Wind Direction (°)

- Height (m AGL)

Graphs showing the variation of these parameters with height.
Sounding: 11 Nov 2012

- Potential Temperature (K)
- Water Vapor Mixing Ratio (g kg\(^{-1}\))
- Wind Speed (m s\(^{-1}\))
- Wind Direction (°)

Graphs show the variation of these parameters with height (m AGL) at different times.
Meteorology at the fire front do not represent ambient conditions.

The FFP is characterized by:

- Increase in velocity field $u$, $v$, $w$, and temperature, $T$.
- Surface wind reversal
- Peak in turbulence and sensible heat flux.
- Minimum in atmospheric pressure
- Strength of each determines fire-atmosphere coupling.
Tower Instrumentation

Two 3-D sonic anemometers: (ATI, SATI-Sx probe) 2 m and 6 m AGL

Fine-wire thermocouples (Omega, Inc), every 1 m, 1-9 m AGL

Hukseflux SBG-01: total heat flux radiometer: 2.8 m

Medtherm 64: radiative heat flux radiometer: 2.8 m

Campbell Scientific Inc, CR3000 data logger, CFM card reader, 2 GB card

Clock locked to GPS

Raw data sampled at 10 Hz; TCs at 5 Hz
Raw 10 Hz time series of $u, v, w, t_s$ are:

1. Despiked using $3\sigma$ for pre, and post FFP

1. FFP is visually inspected (or despiking is applied).

2. 30 min $u, v$ rotated into stream-wise, cross-wind directions; $w$ is tilt-corrected (planar-fit method).

1. 15 min average is used to calculated perturbations for turbulent statistics
Data Processing: Turbulence Spectra

- Wind velocity and temperature (10 Hz):
  - U: mean wind direction
  - V: lateral wind direction
  - W: tilt-corrected, vertical velocity
  - Ts: sonic temperature

- Define Pre-, During-, Post-Fire Front Passage (FFP)

- Fast Fourier Transform (FFT) / Wavelet Transform
Turbulent Kinetic Energy (TKE) is the sum of velocity variances:

$$TKE = \frac{1}{2}\left(\overline{u'^2} + \overline{v'^2} + \overline{w'^2}\right)$$

Turbulent Sensible Heat Flux (Hs) is calculated by eddy-covariance from

$$H_s = \rho c_p \overline{w'T'}$$

To isolate FFP, 1 min averages are calculated
Time Series: 10 Hz processed

S7

- u (m/s)
- v (m/s)
- w (m/s)
- Ts (°C)

S8

- u (m/s)
- v (m/s)
- w (m/s)
- Ts (°C)

S9

- u (m/s)
- v (m/s)
- w (m/s)
- Ts (°C)
Tower Time Series: 10 Hz processed
Turbulence Kinetic Energy and Heat Flux

L1G

L2G

L2F

TKE (m²/s²)

Hs (kW/m²)

Time (CDT)
Convective and Radiative Heat Fluxes
Comparison of Heat Fluxes: Eddy Covariance vs. Radiometric Measurements
Near-Surface Thermodynamic Plume Structure (Plot S3)

Fine-Wire TCs, 1 Hz

Time (CST)

Height (m AGL)

Temperature (°C)
Doppler Lidar deployed during S7
Doppler Radial Velocity and Backscatter: S7
Doppler Radial Velocity and Backscatter: S8

Elevation angle: 2.5°
Doppler Radial Velocity: LG2
Conclusions

• Overall, data quality is high!

• In situ tower data shows FFP structure and fire-atmosphere coupling

• Doppler Lidar scans are able to track plume boundaries

• Lidar beam able to penetrate plume, but some attenuation occurs downstream

Future work
1. Correlate lidar plume boundaries with UAS fire front
2. Calculate turbulent spectra from time series data
3. Compare heat fluxes to others measured
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