COMPARISONS OF MEASUREMENTS AND PREDICTIONS OF PM CONCENTRATIONS AND EMISSION RATES FROM A WIND EROSION EVENT

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Introduction

- Wind erosion removes valuable top soil from agricultural lands and can damage crops

Source: WERU, ARS

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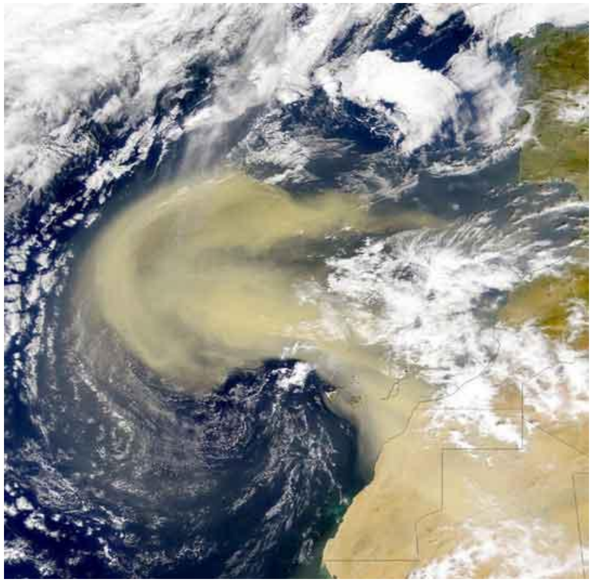
Introduction

- Wind erosion can degrade local, regional, even global air quality and may affect weather patterns



2/26/2000 SeaWiFS image over northwestern Africa
Source: NASA, Earth System Science

7/5/2011 Phoenix, AZ Dust Storm (PM_{10} conc = 6,348 μg/m^3)
Source: AP, Huffington Post

- Understanding and quantifying wind erosion processes, variables, emission rates, and their effects is important

Energy Dynamics LABORATORY
Utah State University Research Foundation

Methodology

- EDL fortuitously measured PM concentrations resulting from a portion of a wind erosion event over a small field in May 2008
  - Conducting an agricultural tillage PM emissions study (not a wind erosion study)
  - Rectangular field near Hanford, CA, with a fine sandy loam soil
  - Surface conditions: fully disturbed, dry, ridges made immediately prior

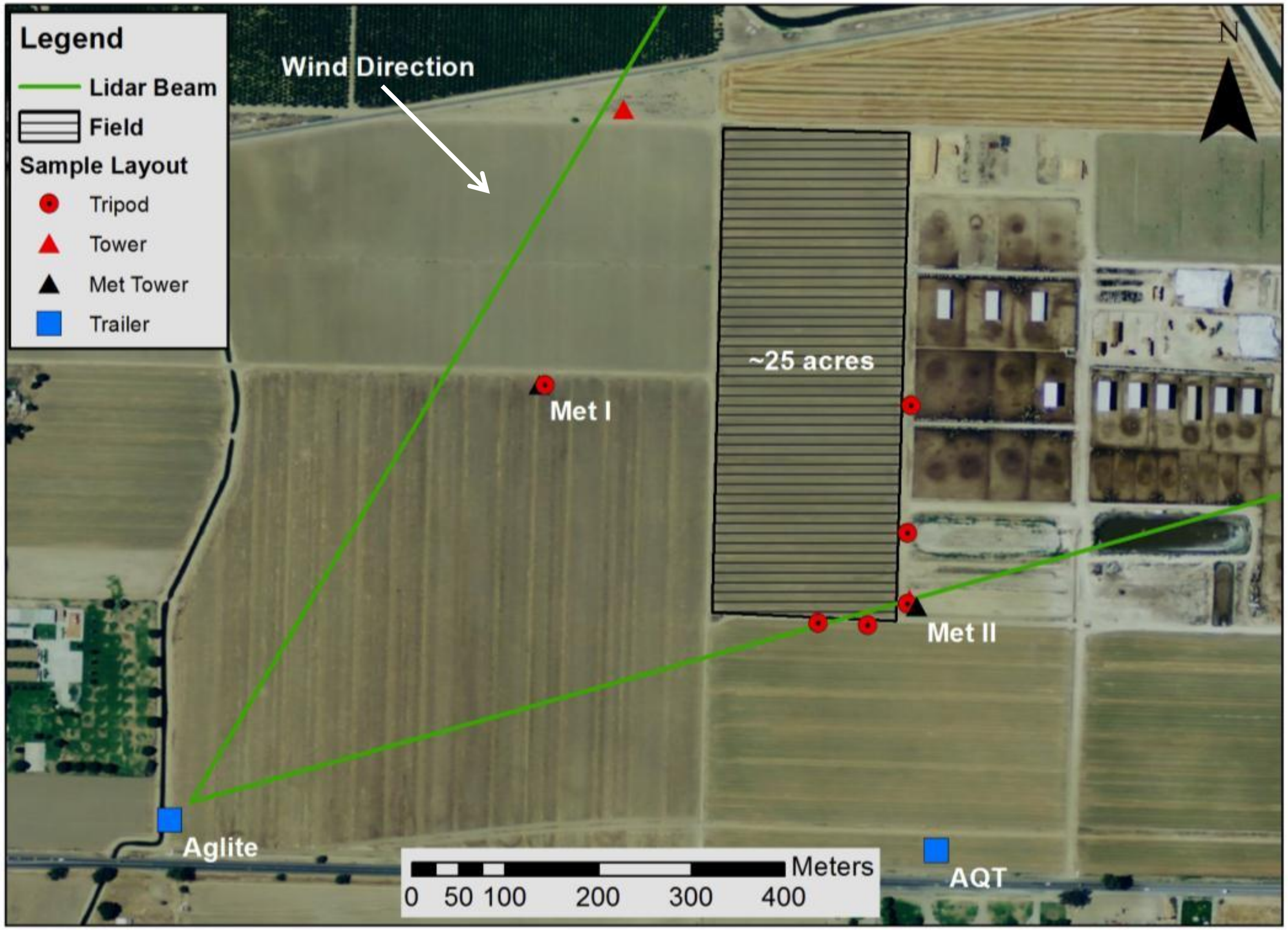
Field condition after making ridges

Methodology

- PM Measurements
  - Point Sensors
    - Met One OPCs (≥ 0.3 μm)
    - Airmetrics MiniVol PM Samplers ($PM_{2.5}$, PM_{10}, TSP)
    - Arrayed horizontally and vertically upwind and downwind
    - OPCs calibrated to mass by MiniVol and OPC relationship (MCF)
  - Aglite Lidar
    - Nd:YAG micropulsed laser at 1064, 532, and 355 nm
    - Vertical and horizontal scanning
    - Aerosol PSD calibration using OPCs
    - Mass calibration using MCF
  - Sample times
    - OPC – 12:50 to 15:45
    - Lidar – 12:50 to 14:00

Methodology

- Site map



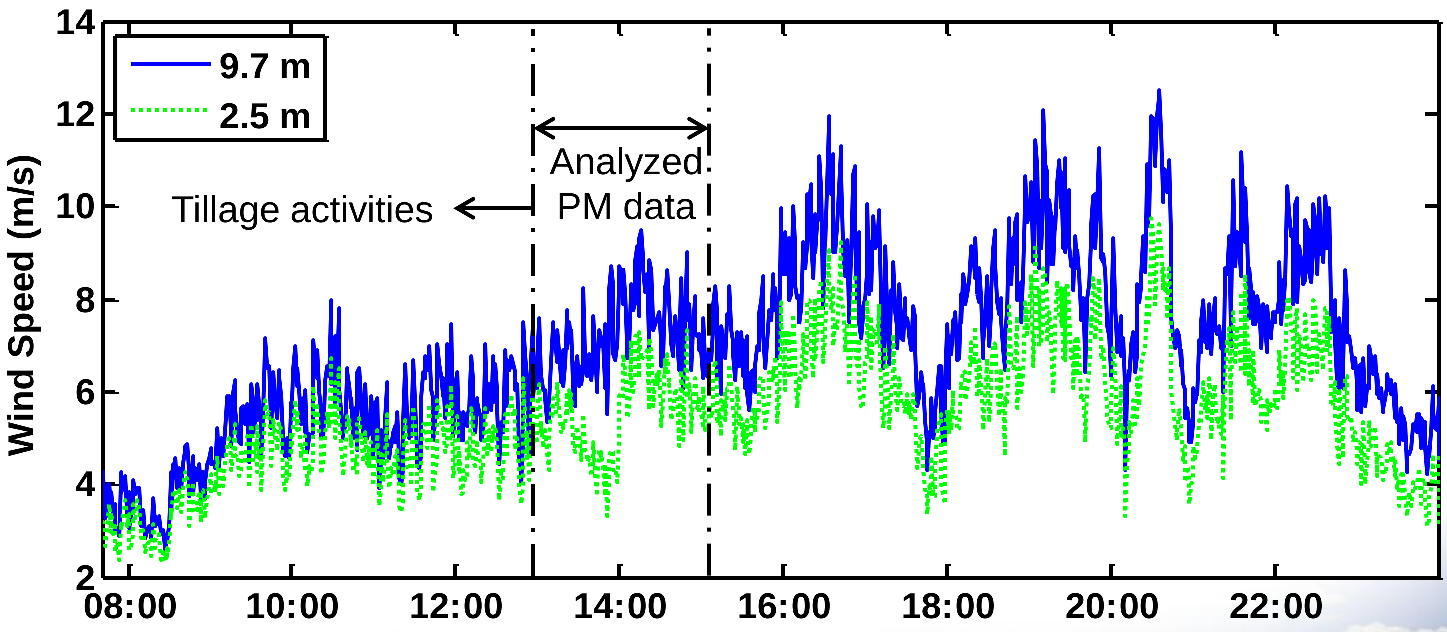
Downwind fetch: 280 m

Methodology

- Emission Rate (ER) Calculations
  - Process-produced concentration: $C_{diff} = C_{downwind} - C_{upwind}$
  - Inverse modeling with OPC PM data and AERMOD
    - Modeling: known ER used to predict concentrations
    - Inverse modeling: initial, lit.-based ER adjusted to best fit C_{diff}
  - Vertical flux method with OPC PM data
    - Inputs: C_{diff} at two heights (z_1, z_2), friction velocity (u_*), k
    - $F_v = \frac{k u_* (C_1 - C_2)}{\ln(\frac{z_2}{z_1})}$
  - Mass balance applied to Lidar PM data
    - $ER = \frac{\sum(C_{diff,z} * wind_z)}{A_{vert.\,plane}}$

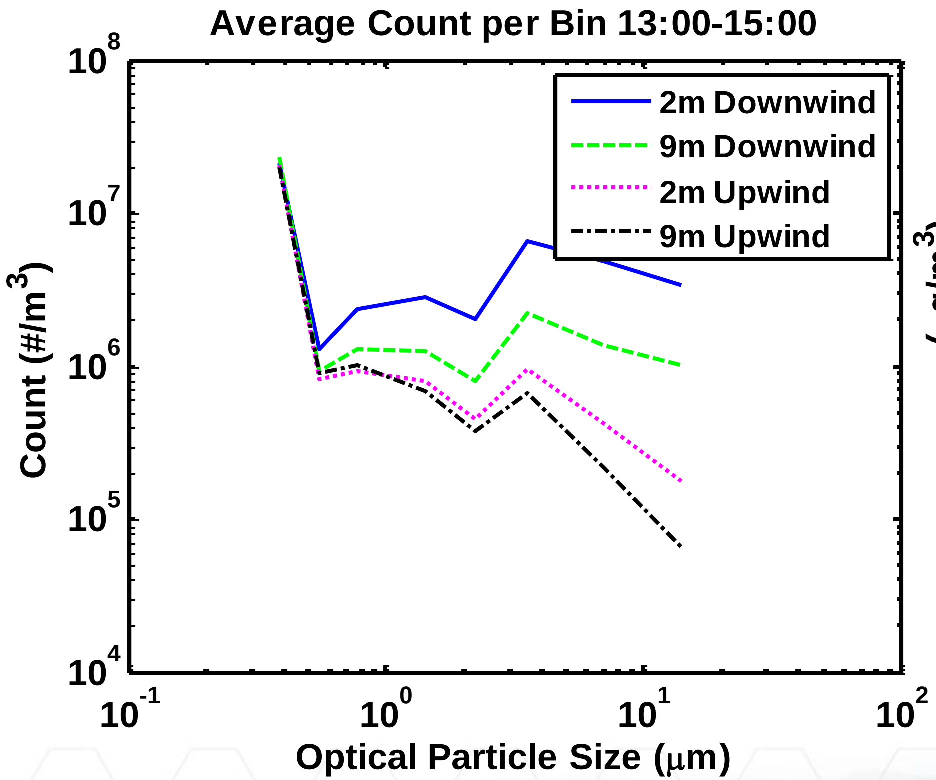
Results

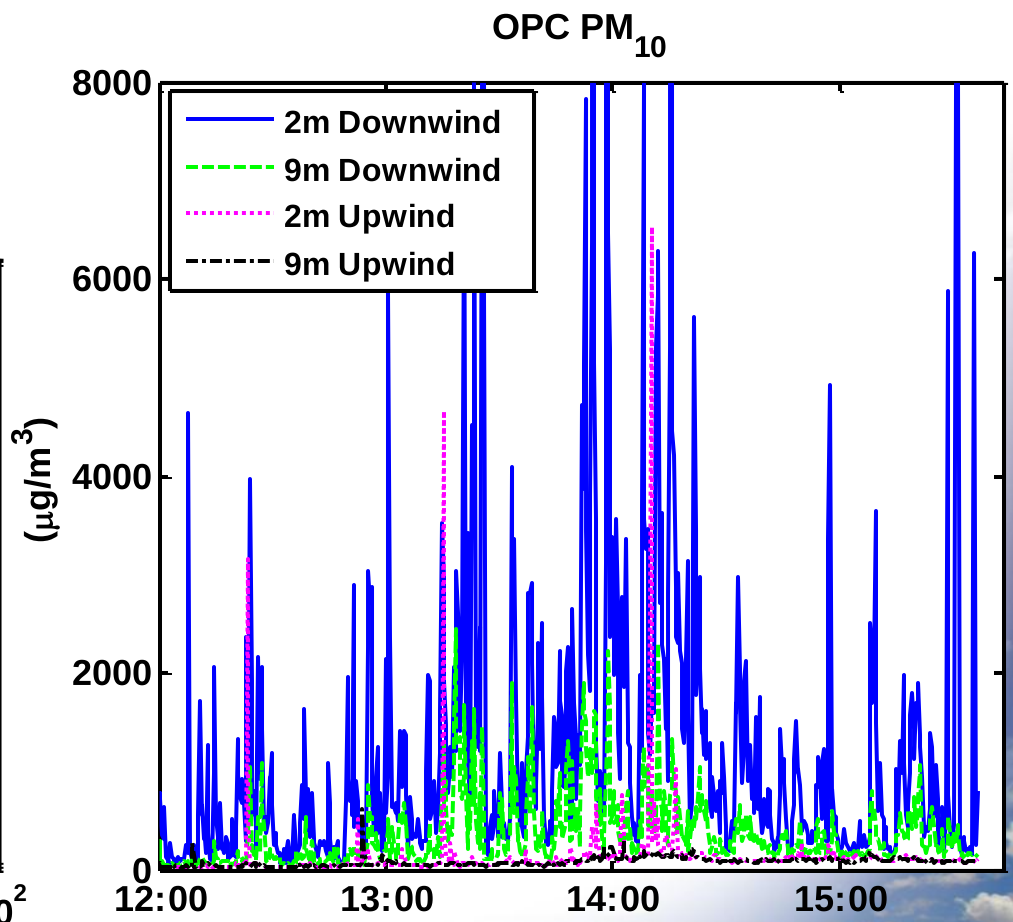
- Meteorology
  - Wind direction: mean = 316º, max = 329º, min = 296º
  - Wind Speed



Results

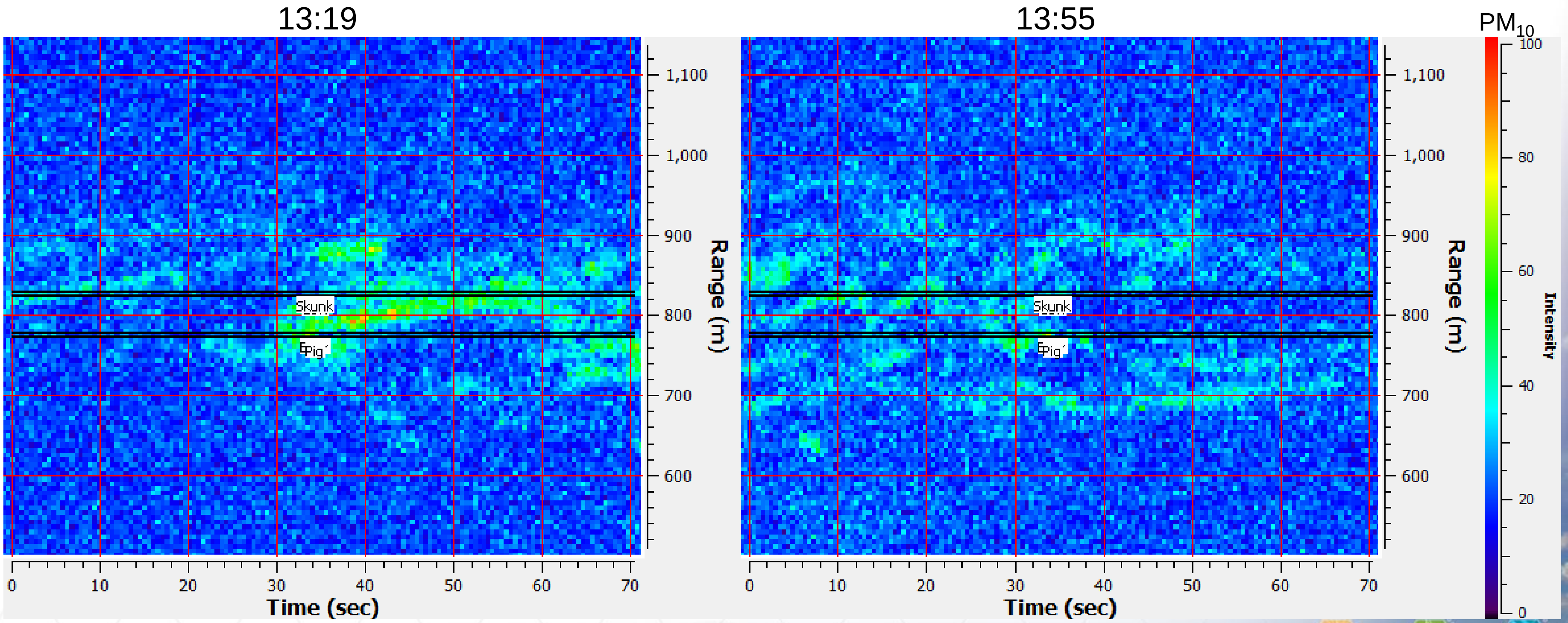
- OPC Measurements





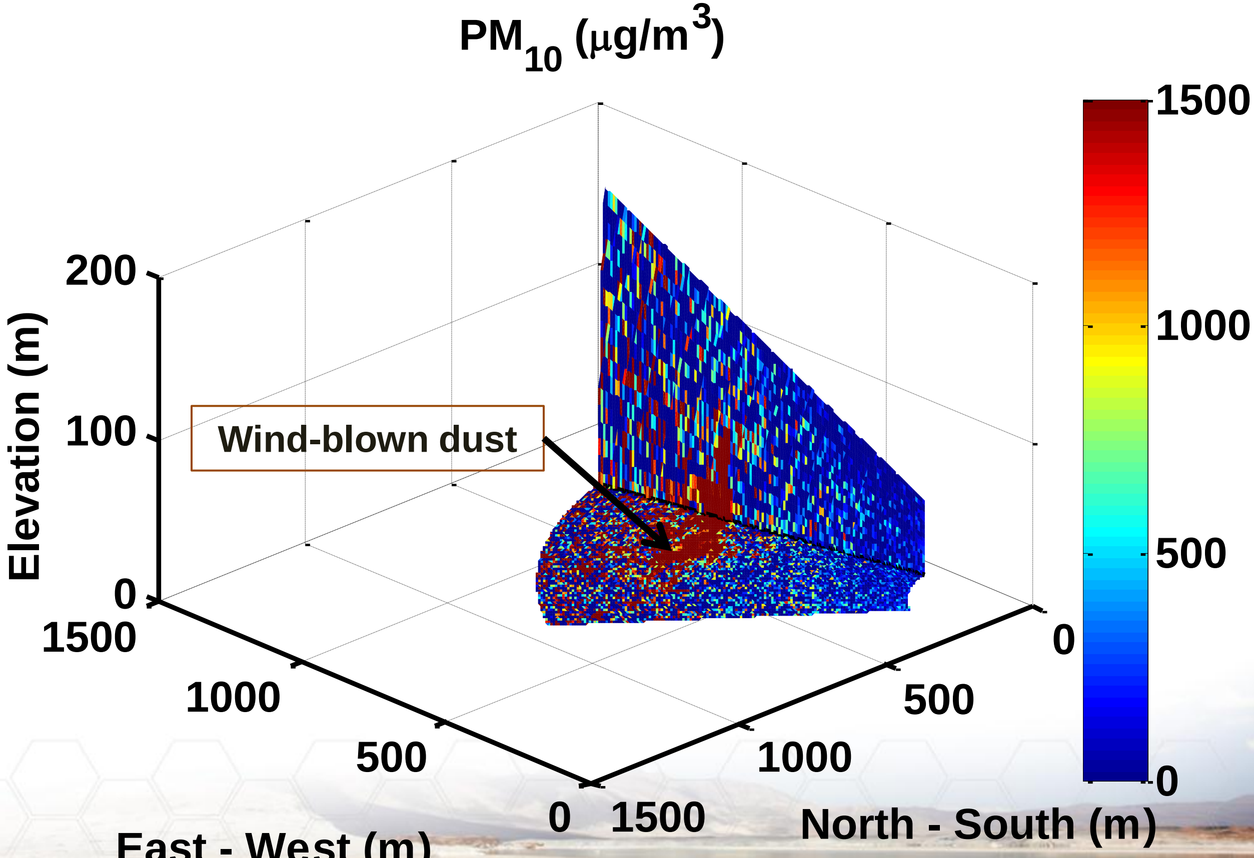
Results

- Lidar Measurements
  - Stare mode at 9 m on downwind field edge



Results

- Lidar Measurements
  - Scanning horizontally over field and vertically on downwind field edge



Results

- Emission Rate Calculations

Method	Time	n (OPC - # samplers, Lidar - # scans)	ERs (µg/s-m^2) PM$_{2.5}$	PM$_{10}$	TSP
Inverse modeling (OPC)	13:00-15:00	3	6.1	268.7	1,488.9
Vertical flux (OPC)	13:00-15:00	2	3.9	174.2	872.0
Mass balance (Lidar)	12:50-13:50	39	0.005 ± 0.006	0.137 ± 0.169	0.645 ± 0.801

Observed wind-blown dust (looking into the wind)

Conclusions

- OPCs and Lidar instruments successfully measured PM levels produced by high winds (6-10 m/s) over a freshly tilled field
- PM levels decreased significantly from 2 m to 9 m
- Lidar measured wind-blown dust plumes of varying size, location, and duration up to 50 m high
- PM_{10} ERs from inverse modeling and vertical flux method are similar to other values found in literature
- Lidar could not measure below ~10 m due to safety concerns, which is a partial explanation for the 10^3 difference between mass balance ERs and inverse modeling and vertical flux methods

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