The Miniature PI-SWERL: A tool for wind-borne suspension studies

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Who cares about wind-borne suspension?

- Suspension of dust or other aerosols contributes to local/regional criteria pollutants like PM_{10}
- Soils may be contaminated
  - Toxic compounds
  - Radionuclides
- Wind erosion can degrade a landscape and impact land use options

Options for estimating wind-borne suspension of soils

- On-site ambient monitoring
  - Gives single point concentrations
- Modeling emissions from meteorology and assumptions about soil behavior
  - Good luck with that

✓ Estimating emissions from meteorology, **on-site measurements of wind erodibility**, and assumptions about spatial and temporal changes in soil response

Options for measuring wind erosion

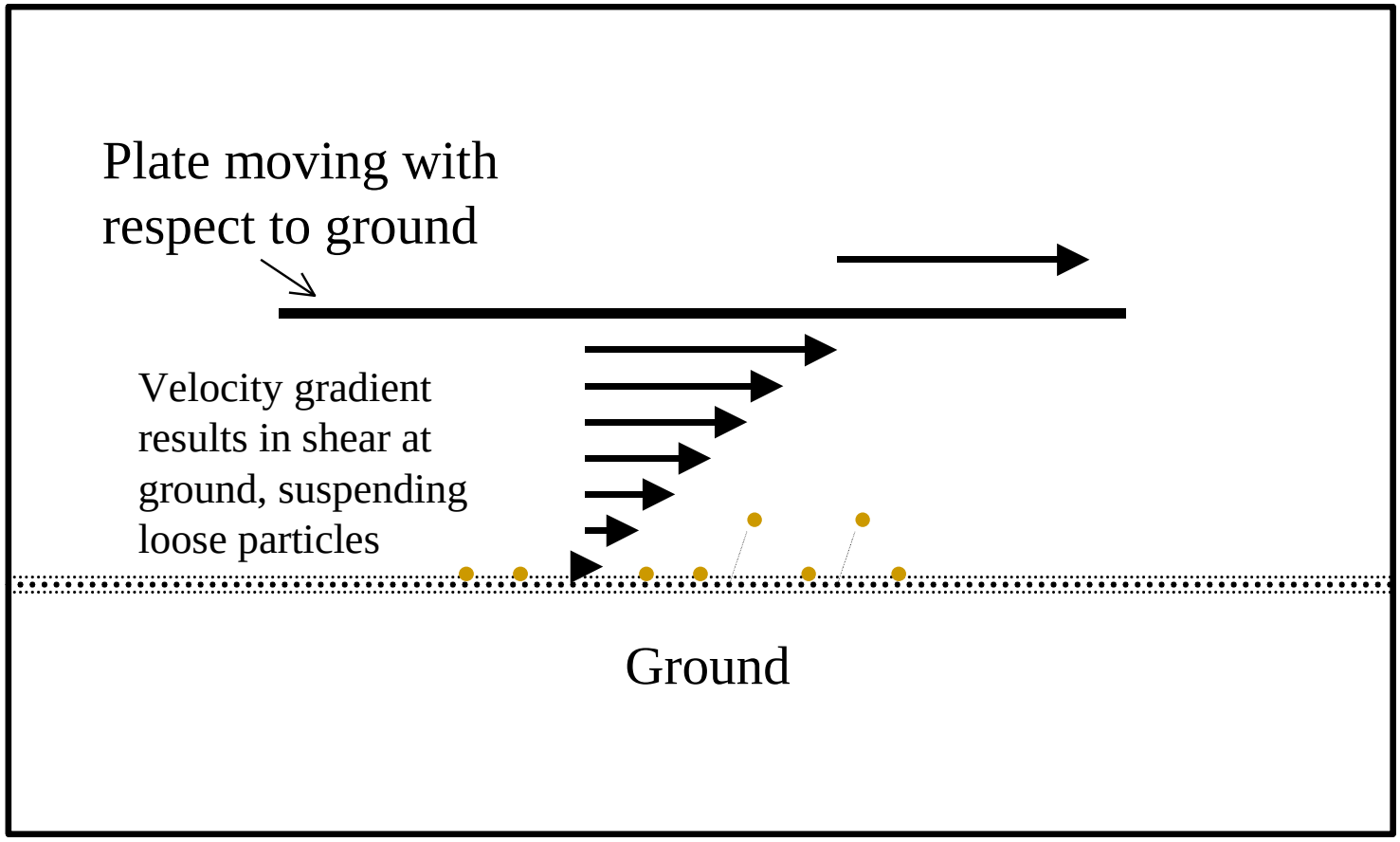
- Sand traps (e.g. BSNE-style)
  - Collect sand over time
  - Relate to dust suspension
- Electronic sensors
  - Measure sand impacts in real-time
  - Relate to dust suspension
- Field wind tunnel
  - Measure sand movement and dust suspension directly

Motivation

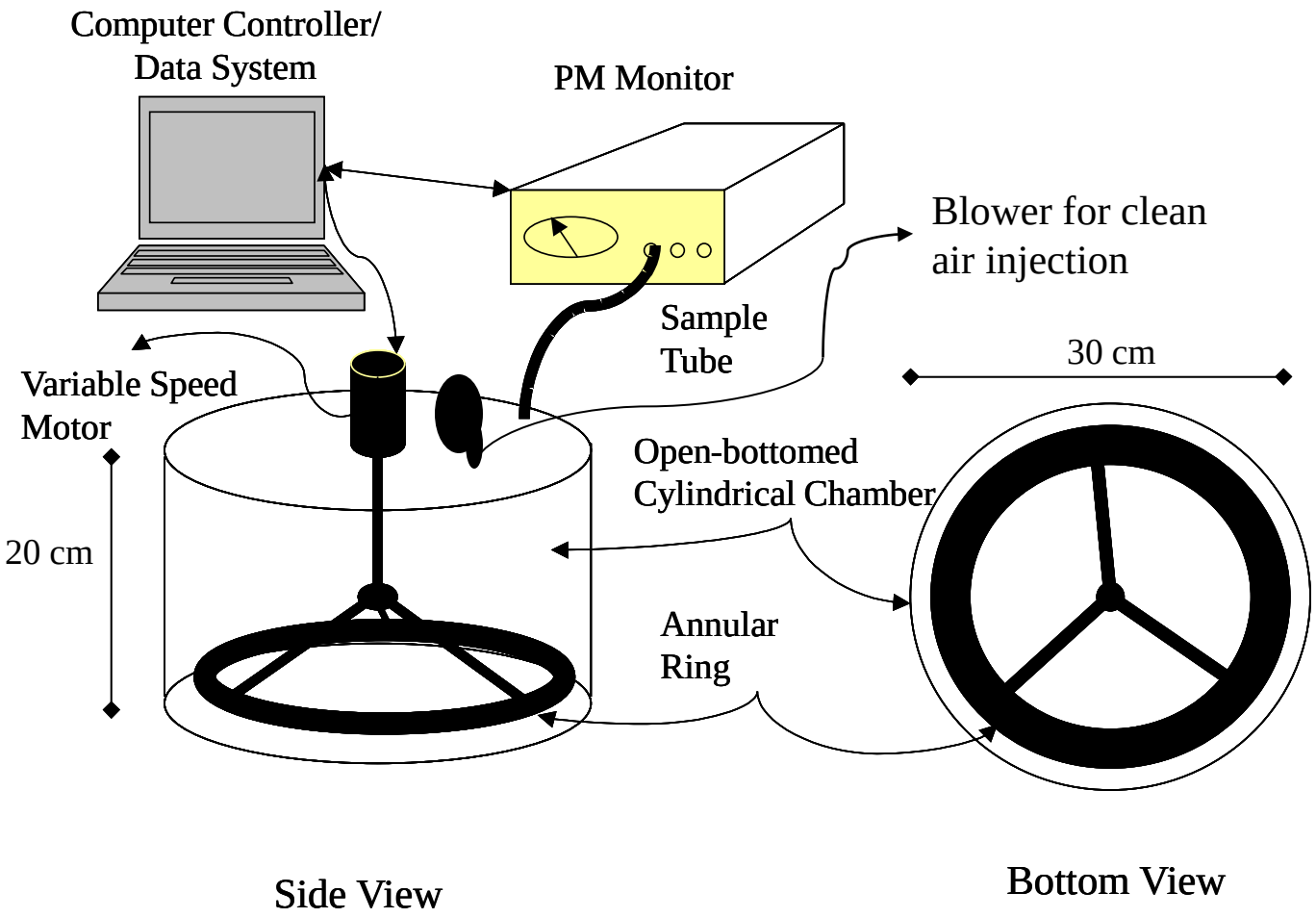
- A Need for in-situ measurement of wind erosion/dust emission
- Field wind tunnels that meet scaling criteria not always practical

Portable In-Situ Wind ERosion Laboratory: The PI-SWERL concept

Philosophy: Don't try to simulate atmospheric flow, instead simulate shear stress experienced by soil surface (i.e. u^*)



PI-SWERL Schematic

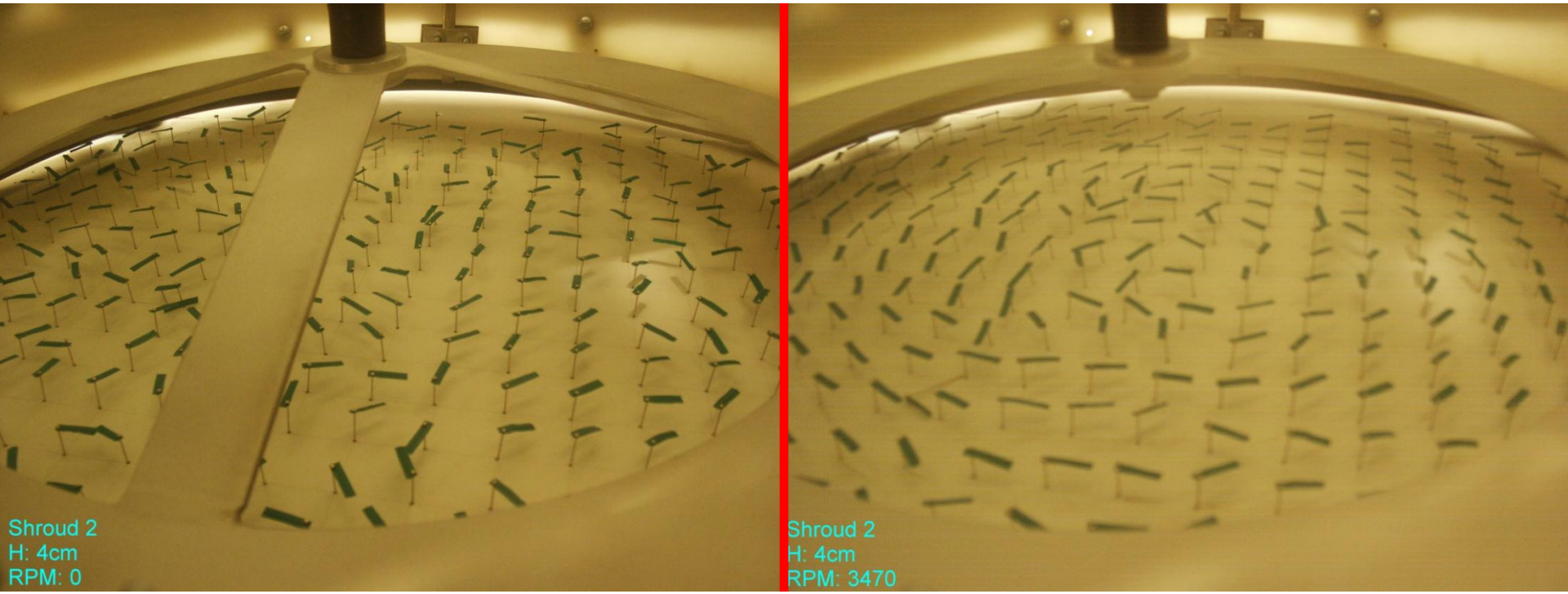


Advantages/Disadvantages

- Advantages
  - Fast, semi-portable, measures index based on shear stress
  - Symmetry bypasses boundary layer issue
  - Geometry allows simulation of “saltation-like” emissions
- Disadvantages
  - Shallow boundary layer
  - Saltation effects probably not accurately captured

Original PI-SWERL

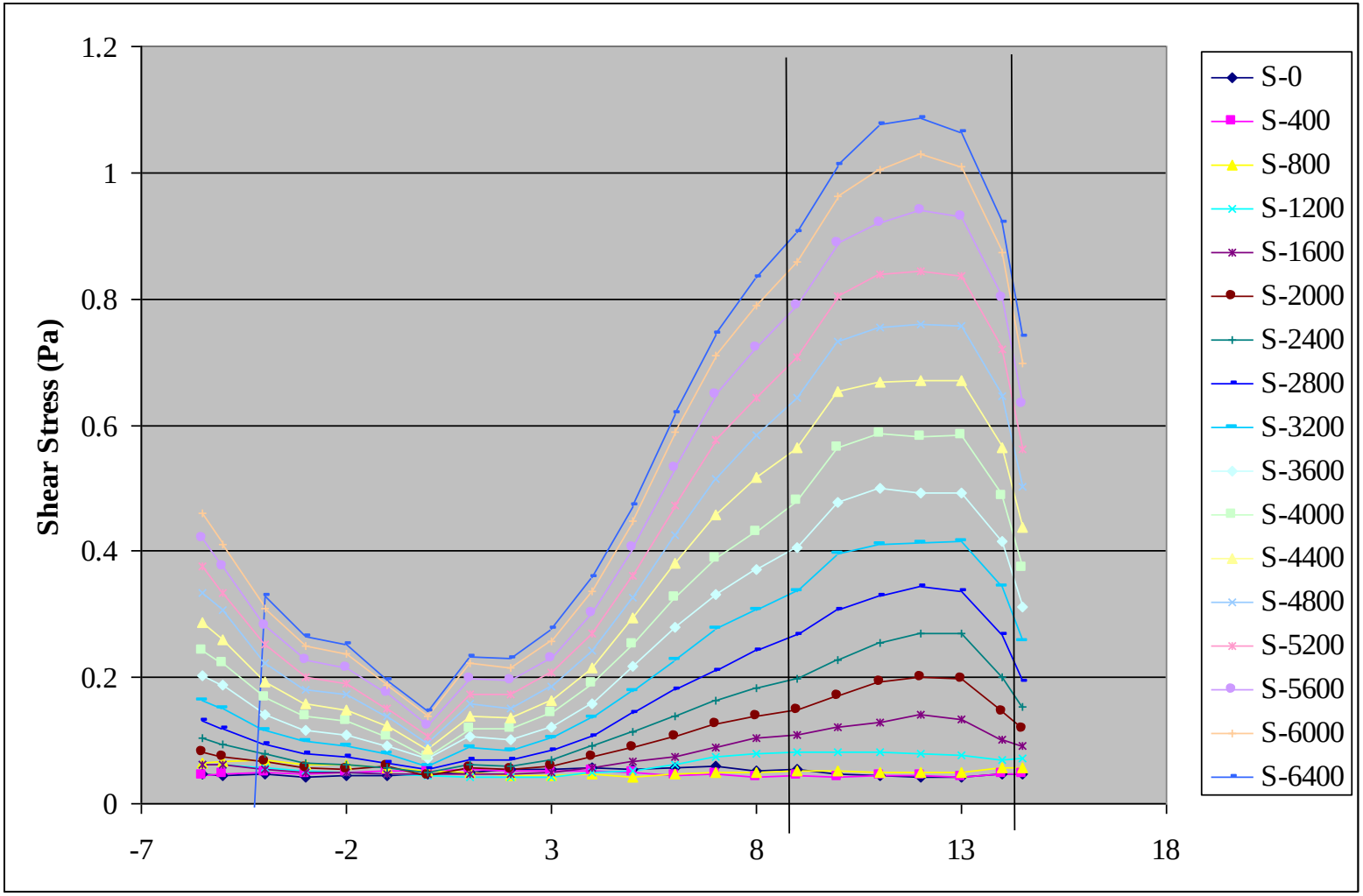
Wind Vectors in PI-SWERL



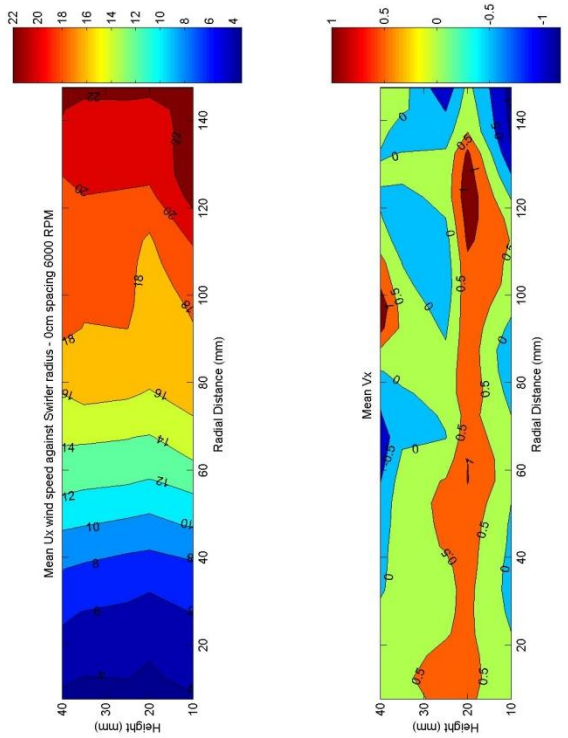
Shaer stress characterization

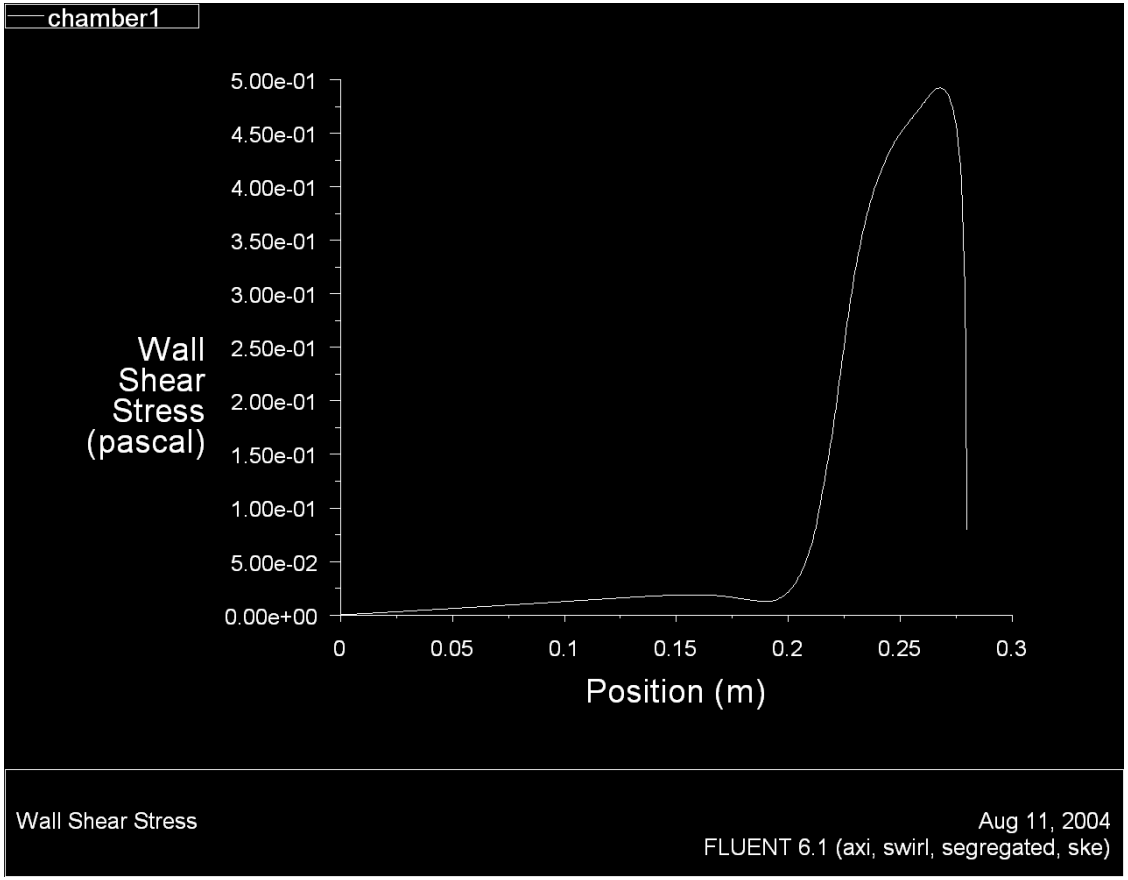
- Wind erosion/soil suspension is related to how much shearing stress the wind applies to the soil
- Need to characterize what shearing stresses PI-SWERL applies to soil
  - Measured with Irwin sensors on smooth surface
  - Varied PI-SWERL RPM and radial location under blade

Shear-stress distribution at ground

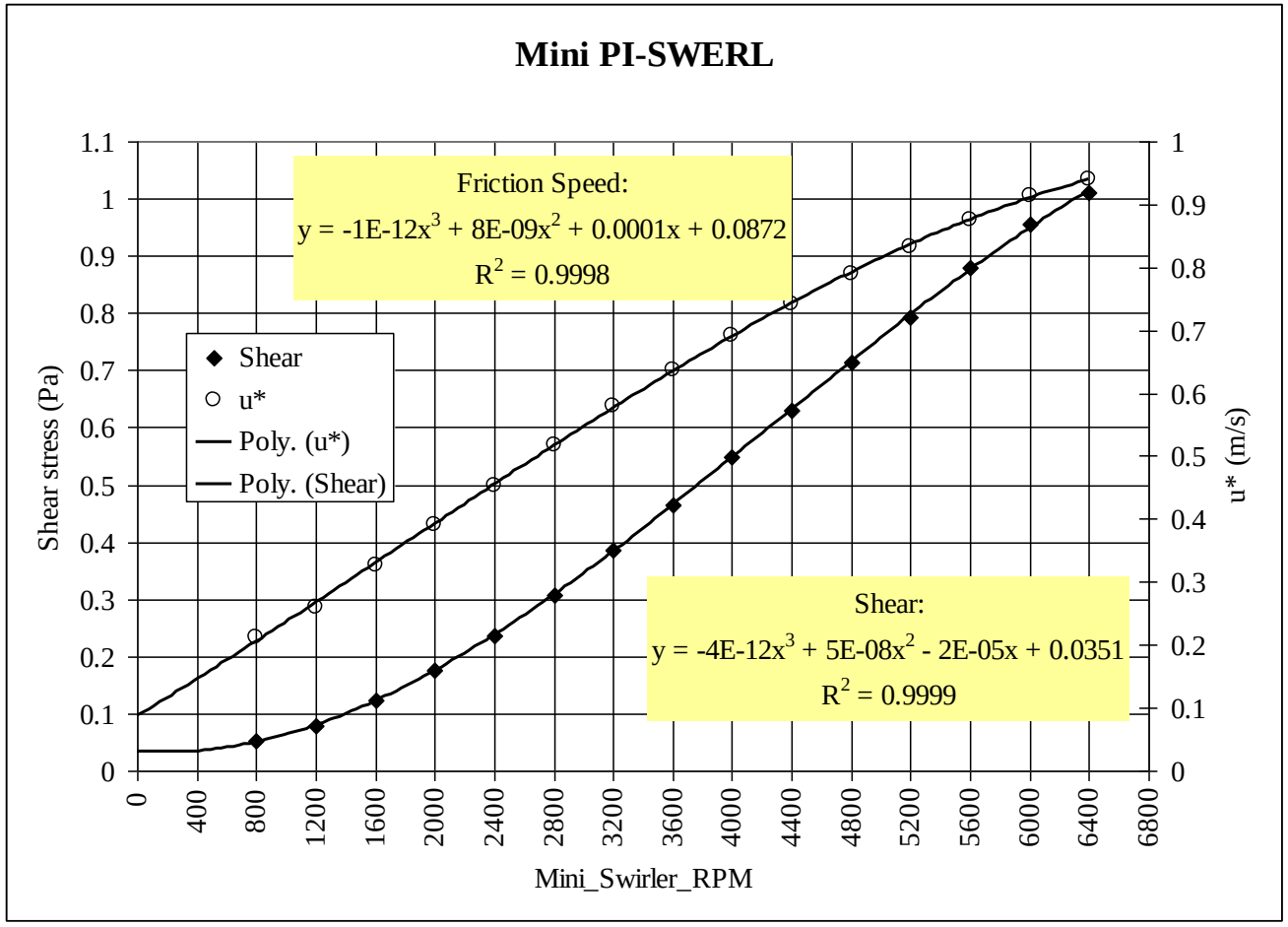


Hot-wire and CFD examples





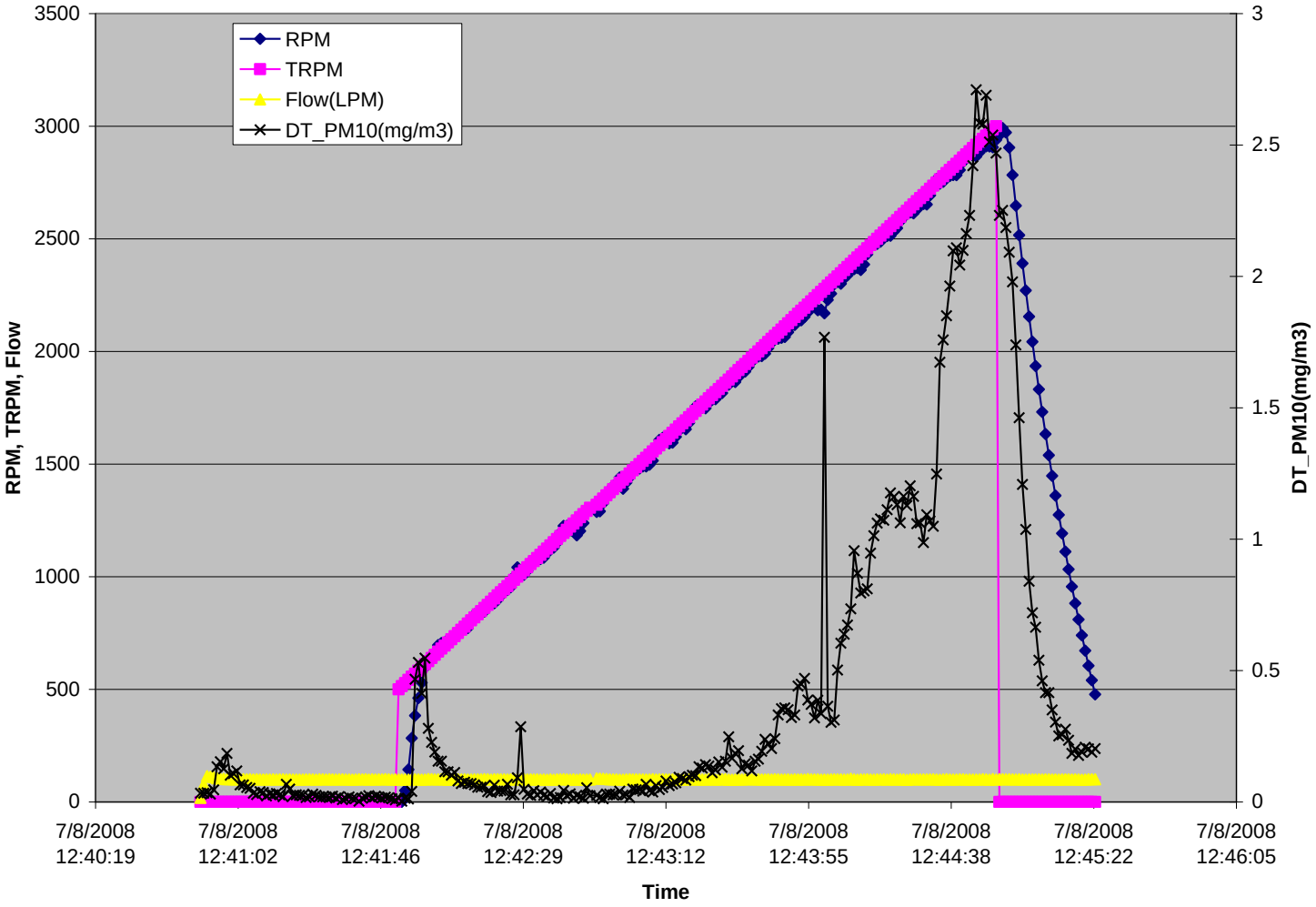
Shear-stress distribution under “effective” area



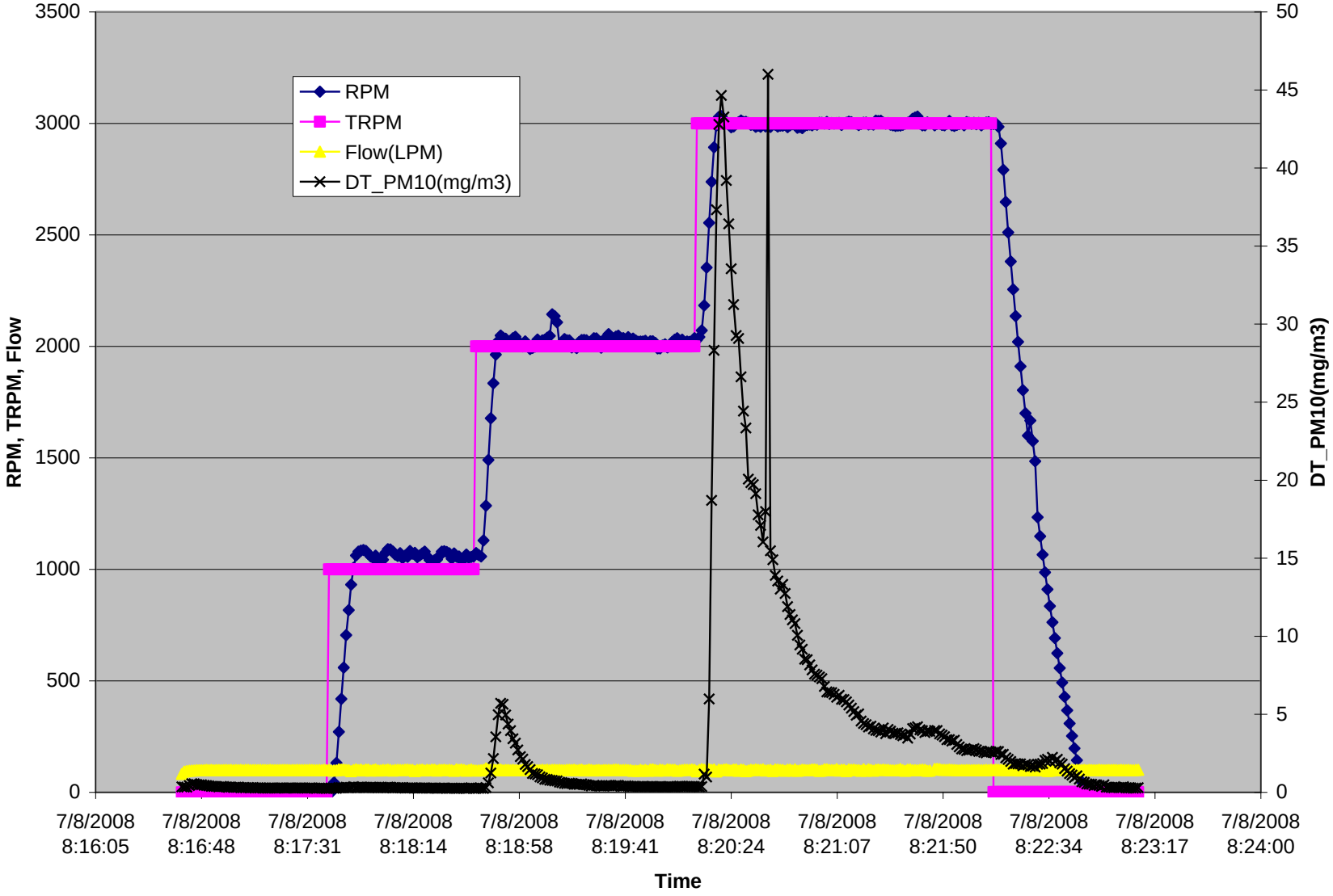
Two types of measurements

- Step test:
  - Hold RPM (shear stress) at fixed value for some period of time
  - Increase RPM to new fixed value and hold
- Ramp Test
  - Gradually increase (linearly) RPM between low and high set value

Ramp Test Example



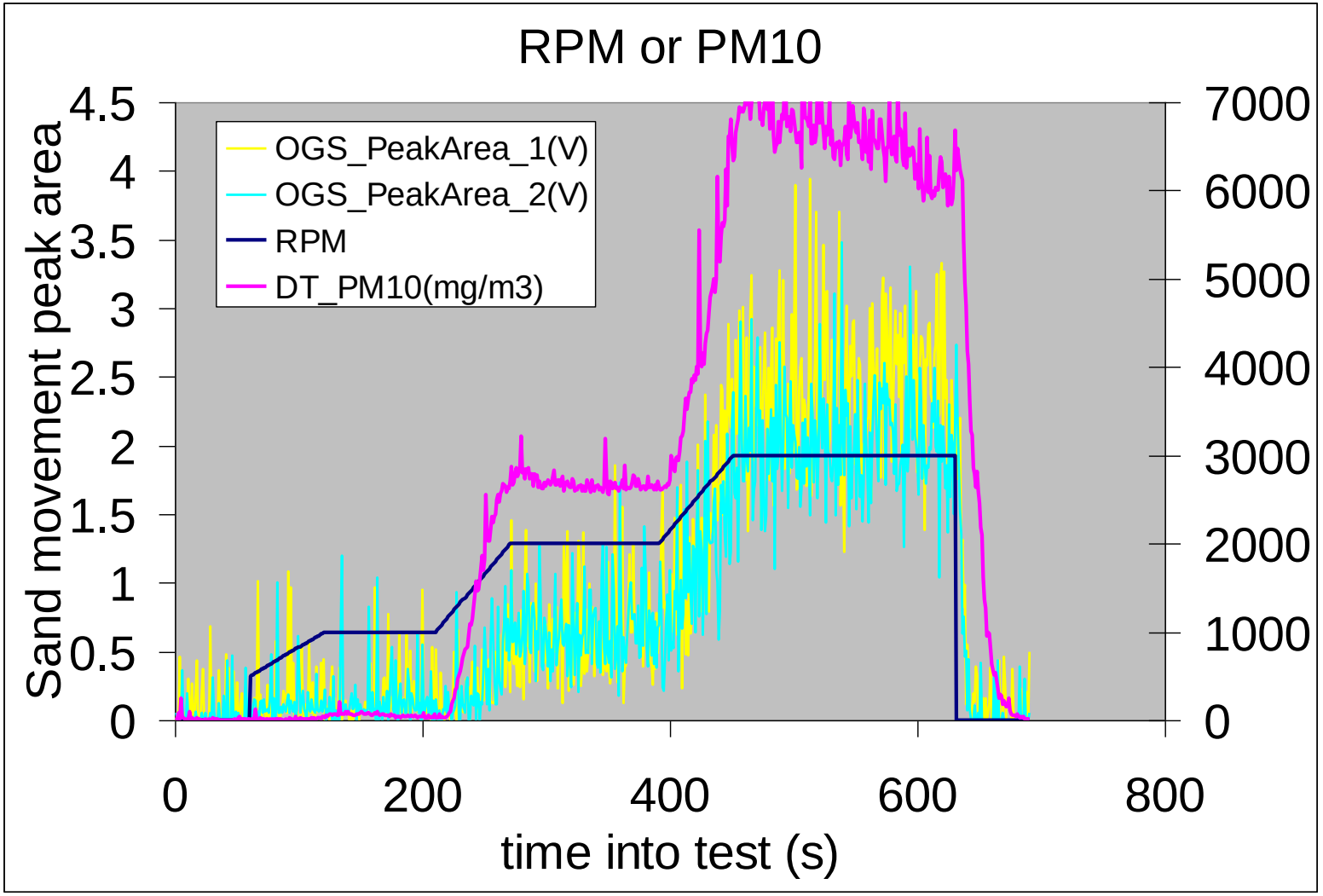
Step Test Example



Which test to use?

- Ramp test ideal for finding the threshold of a surface for dust emissions and initial response to increase in shear-stress
- Step test ideal for measuring dust emission characteristics over prolonged exposure to shear stress
- If both types of information needed, use hybrid test

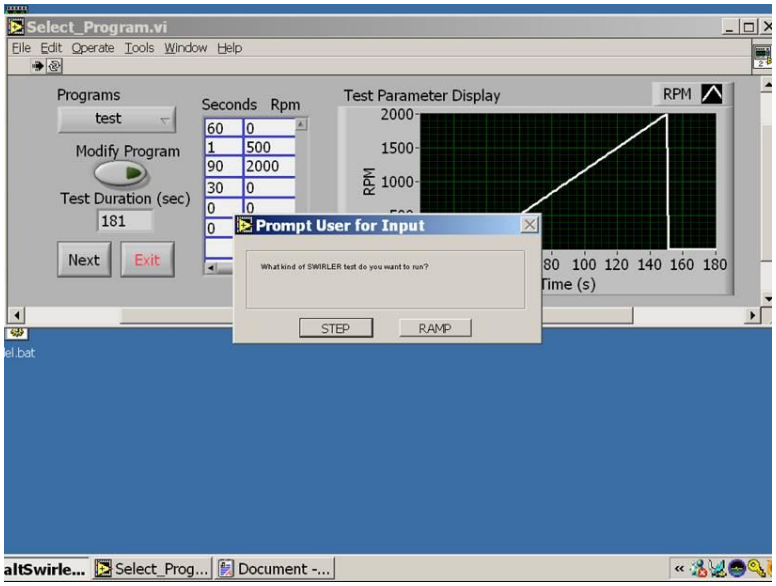
Example hybrid test



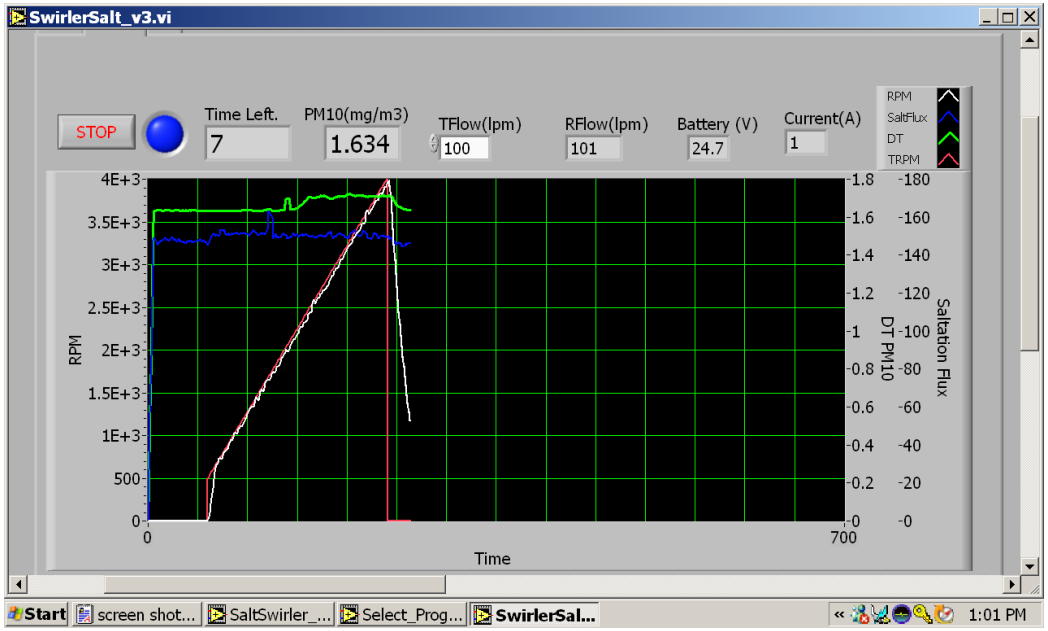
Operating the PI-SWERL

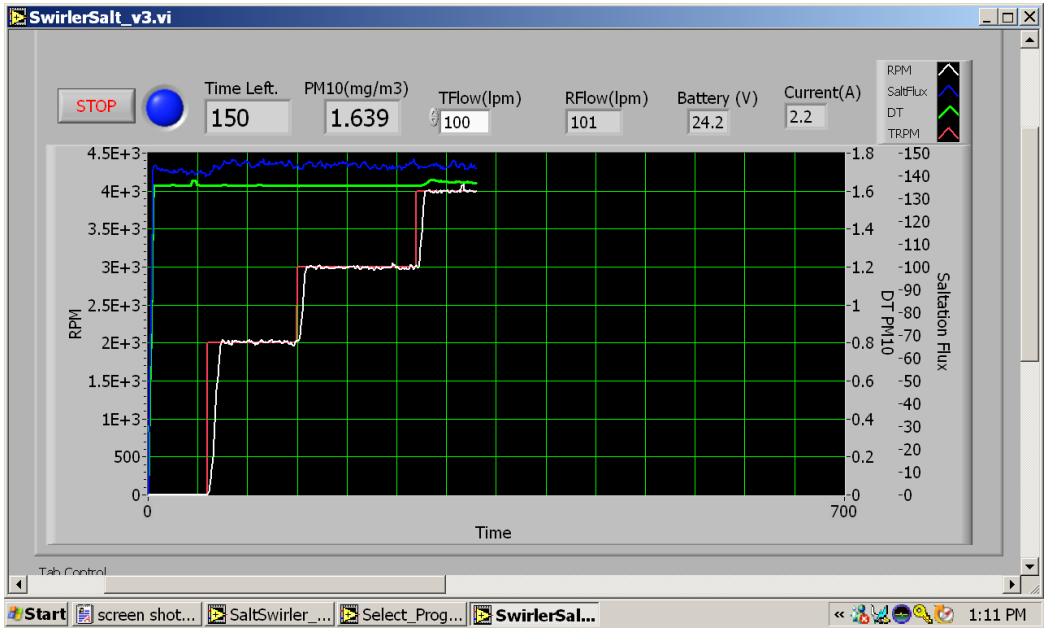
- Place the PI-SWERL on top of suitable test location

Operating the PI-SWERL



SwirlerView Software requires some inputs. During test, SwirlerView, operates PI-SWERL and writes data files

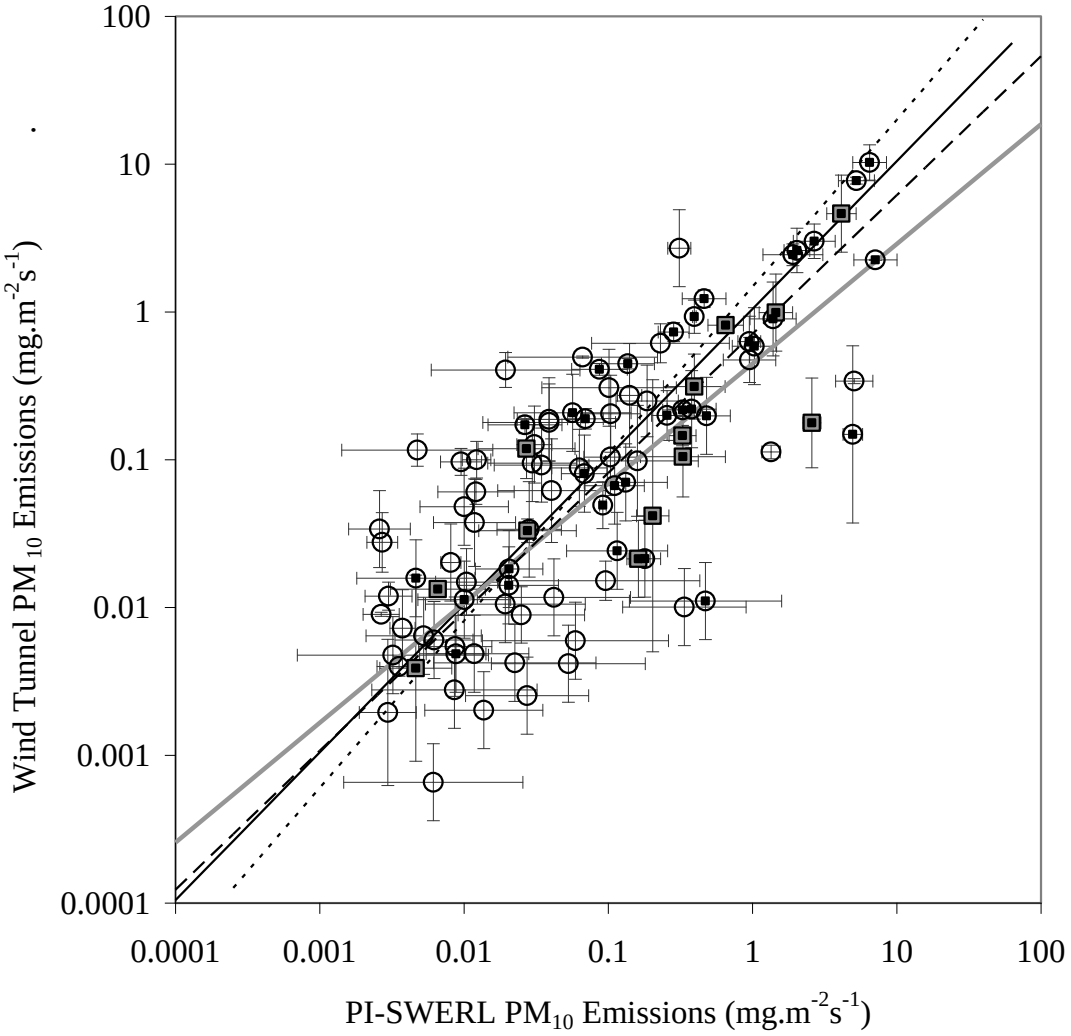




Example Applications so far

- Collocation with university of Guelph field wind tunnel
- Characterizing potential for dust emissions at Salton sea
- Quantifying effectiveness of soil stabilization treatments
- Examining aerodynamic entrainment of dust from roads and unpaved road shoulders.
- Effect of fire on wind erodibility

Collocation with U of G tunnel



Non Gravel Surfaces

Gravel Surfaces

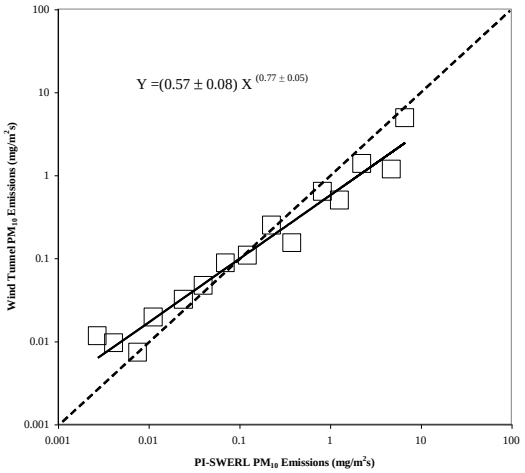
Saltation Above 100 mg/ms

All Data: R=0.76, b=1.0, a=0.02

Non Gravel Surfaces: R = 0.75, b=1.13, a=0.17

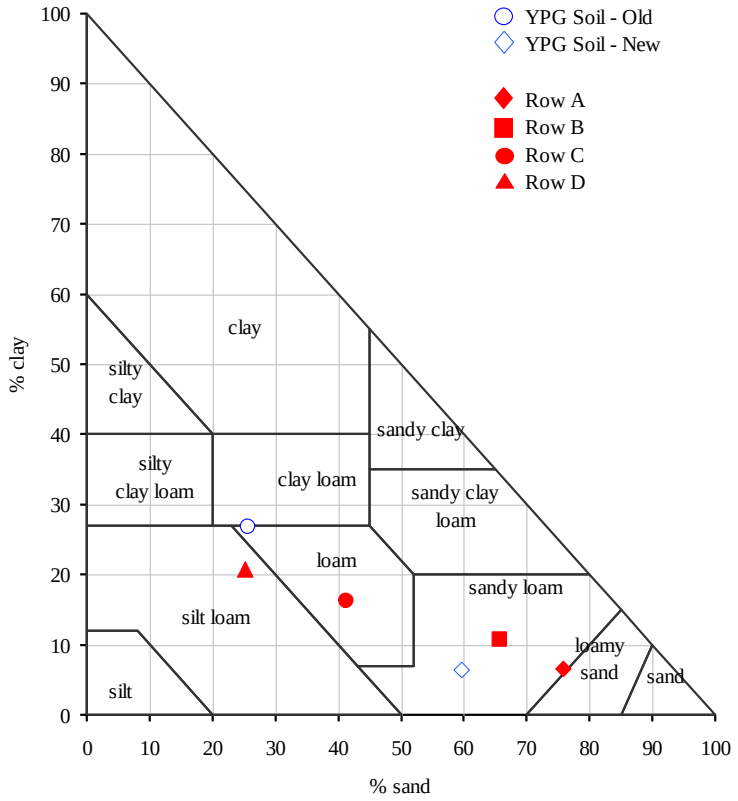
Gravel Surfaces: R=0.85, b=0.81, a=-0.35

Saltation above 100 mg/ms: R=0.81, b=0.94, a=-0.15

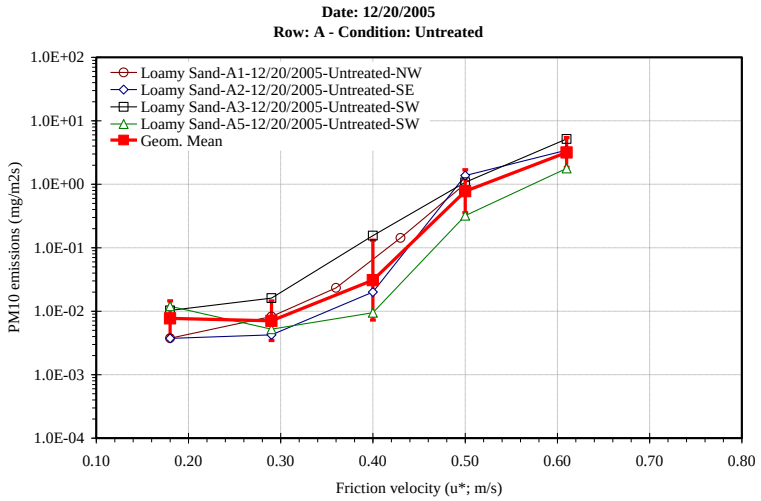


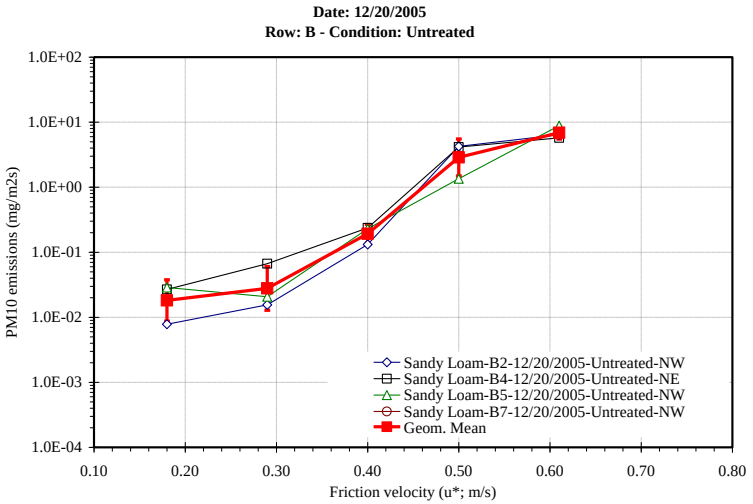
Precision of instrument

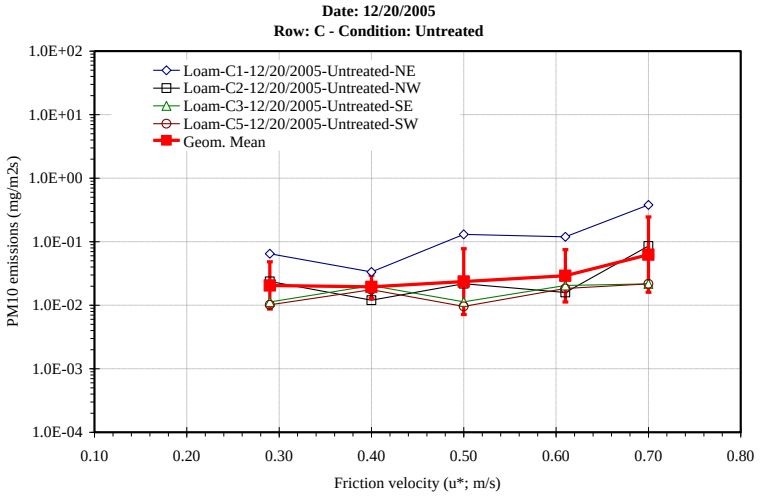
- Beware: surface variability is a different animal
- Precision characterized for constructed soil plots

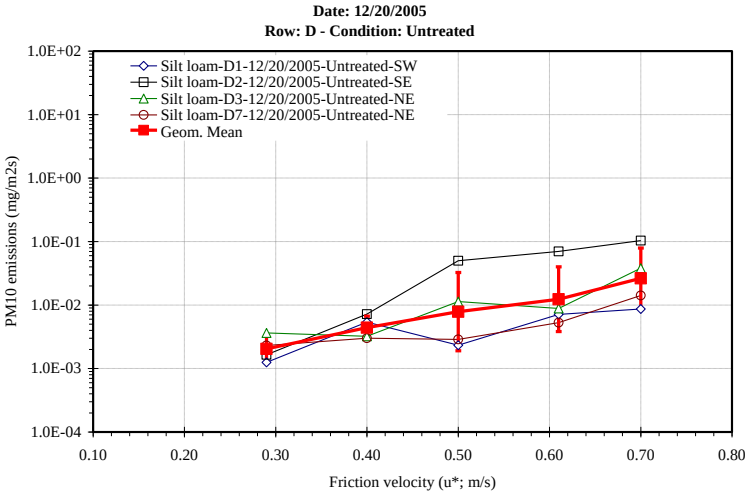


Replicate measurements

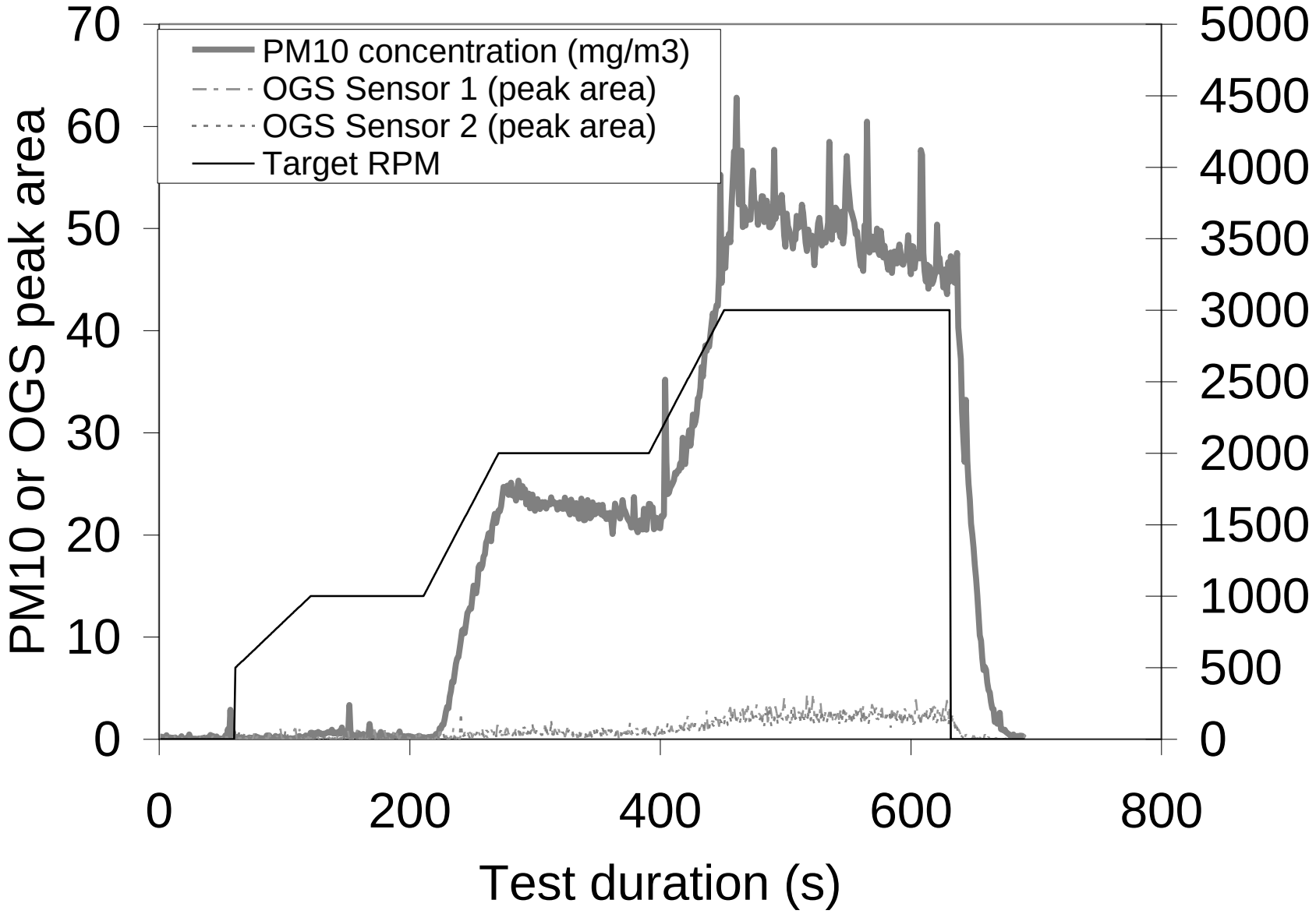




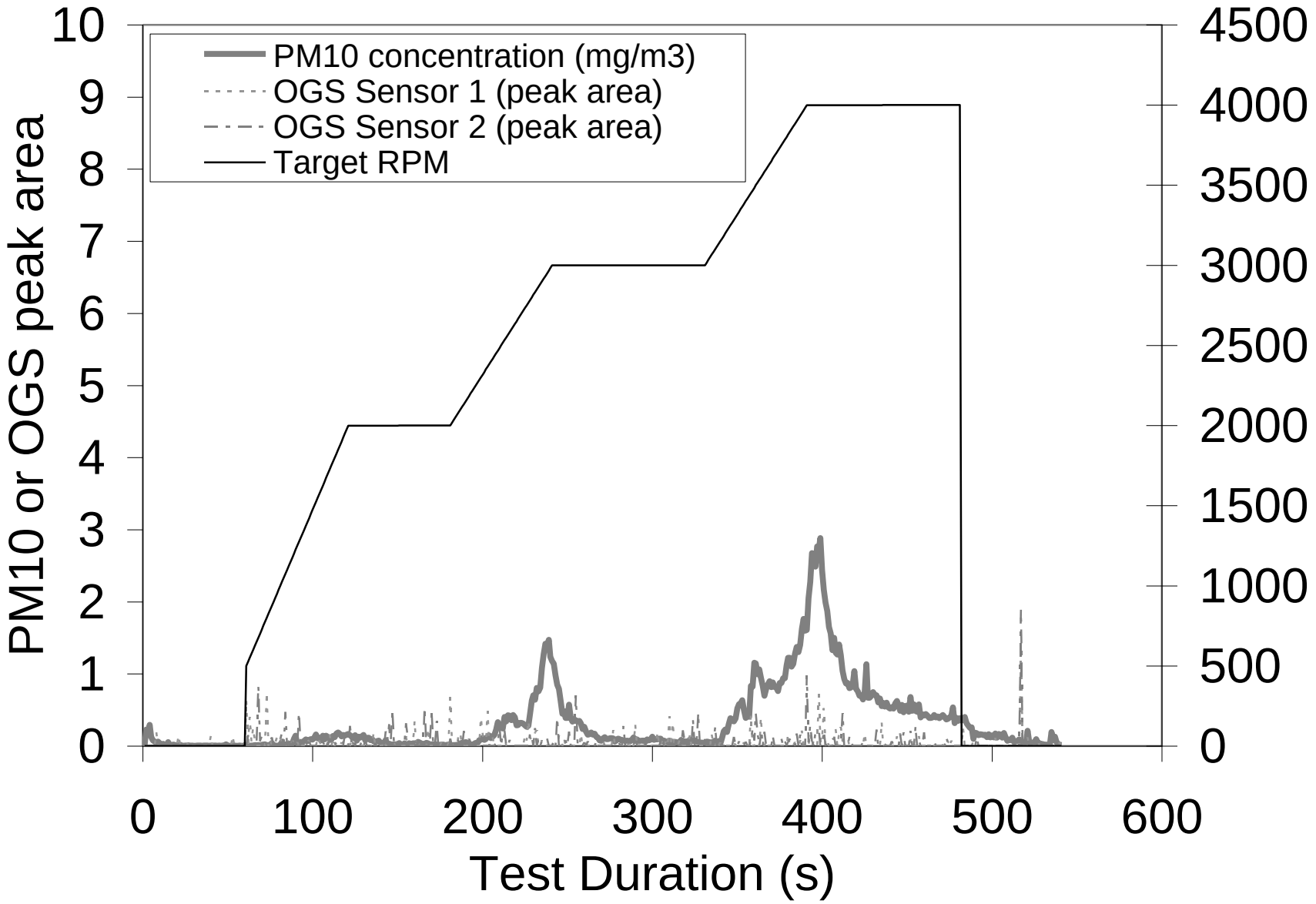




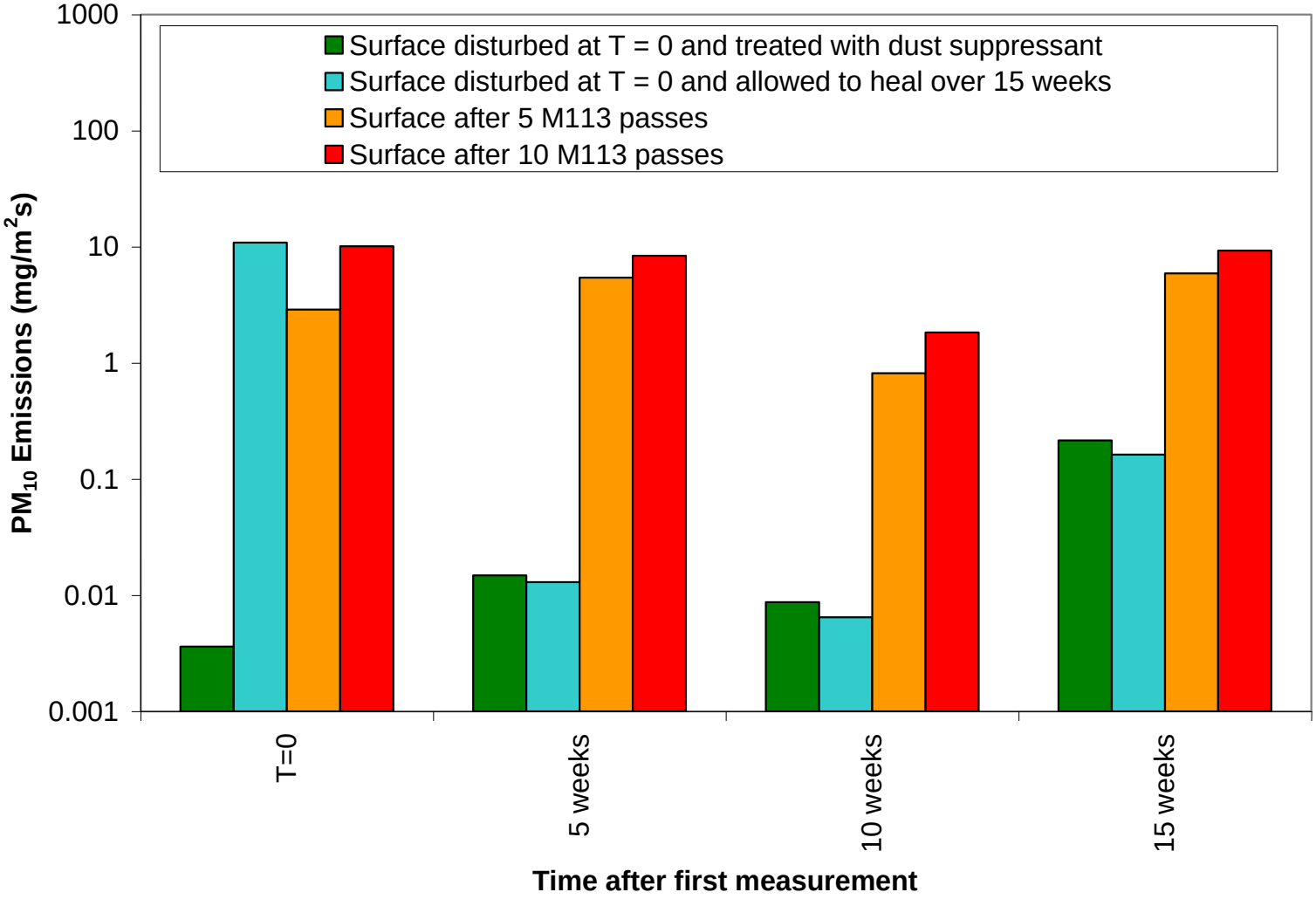
Loose soil, unlimited sand



Supply-limited surface

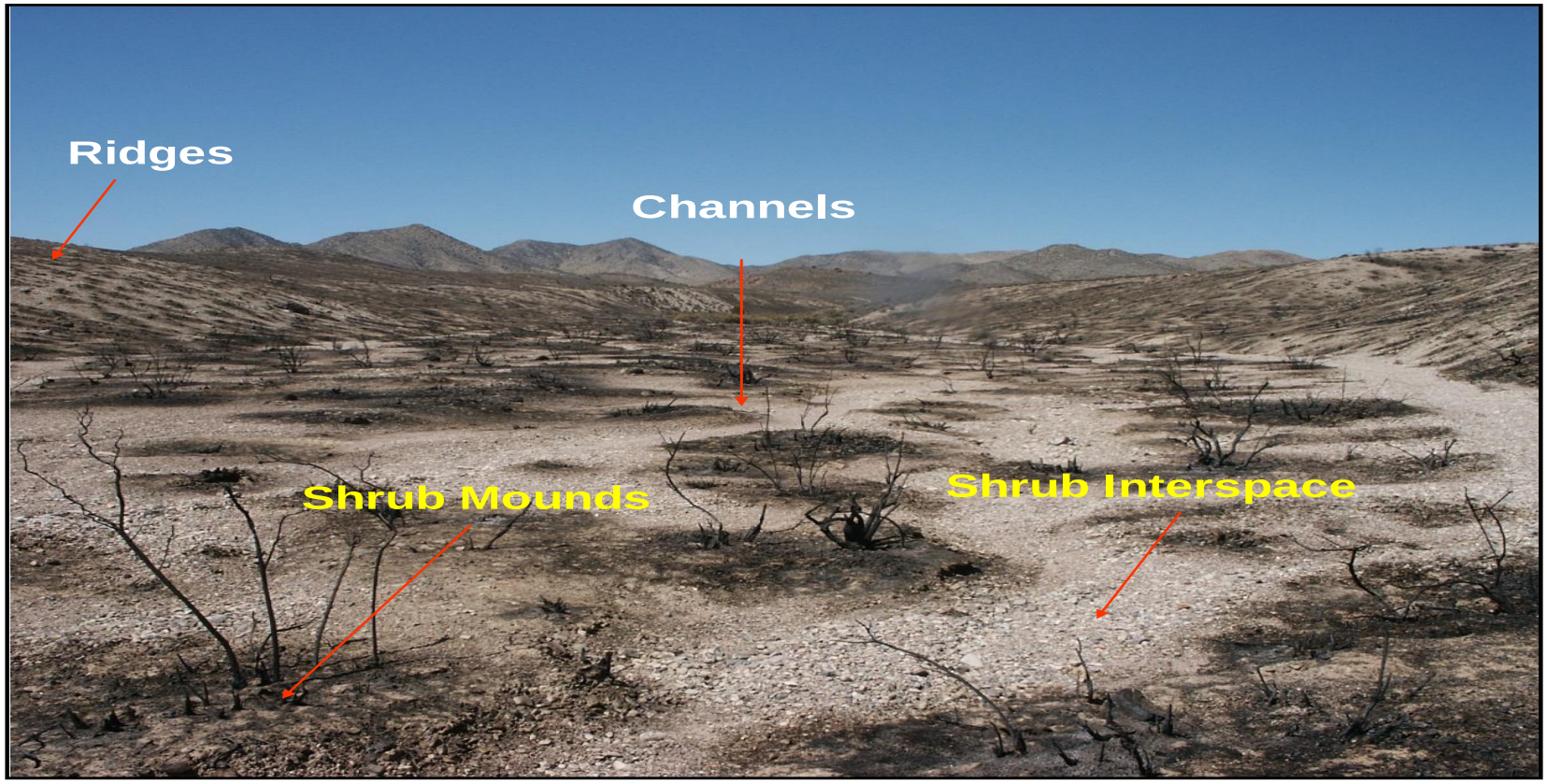


Aggregate information at specific value of u*

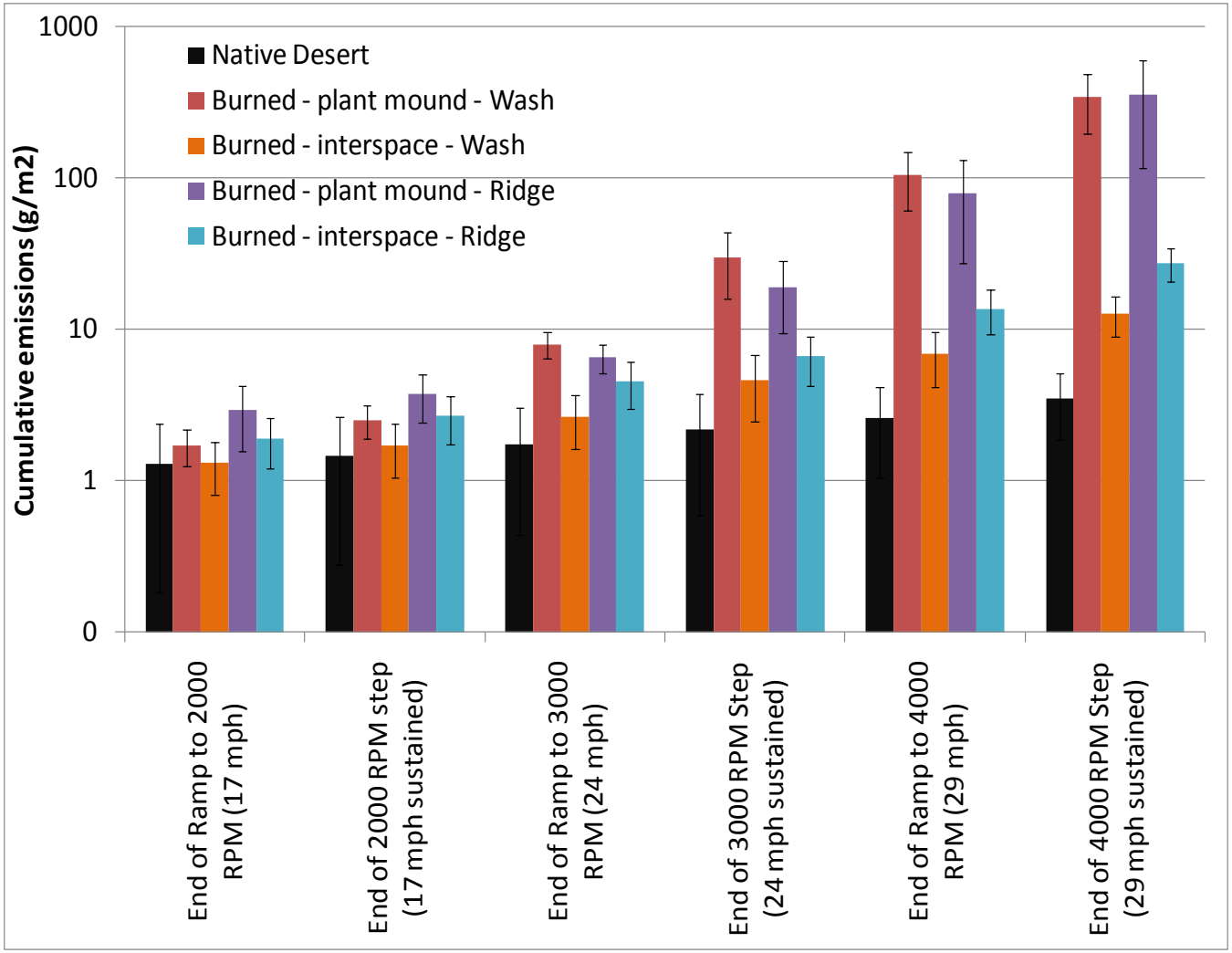


Effect of fire on wind erodibility

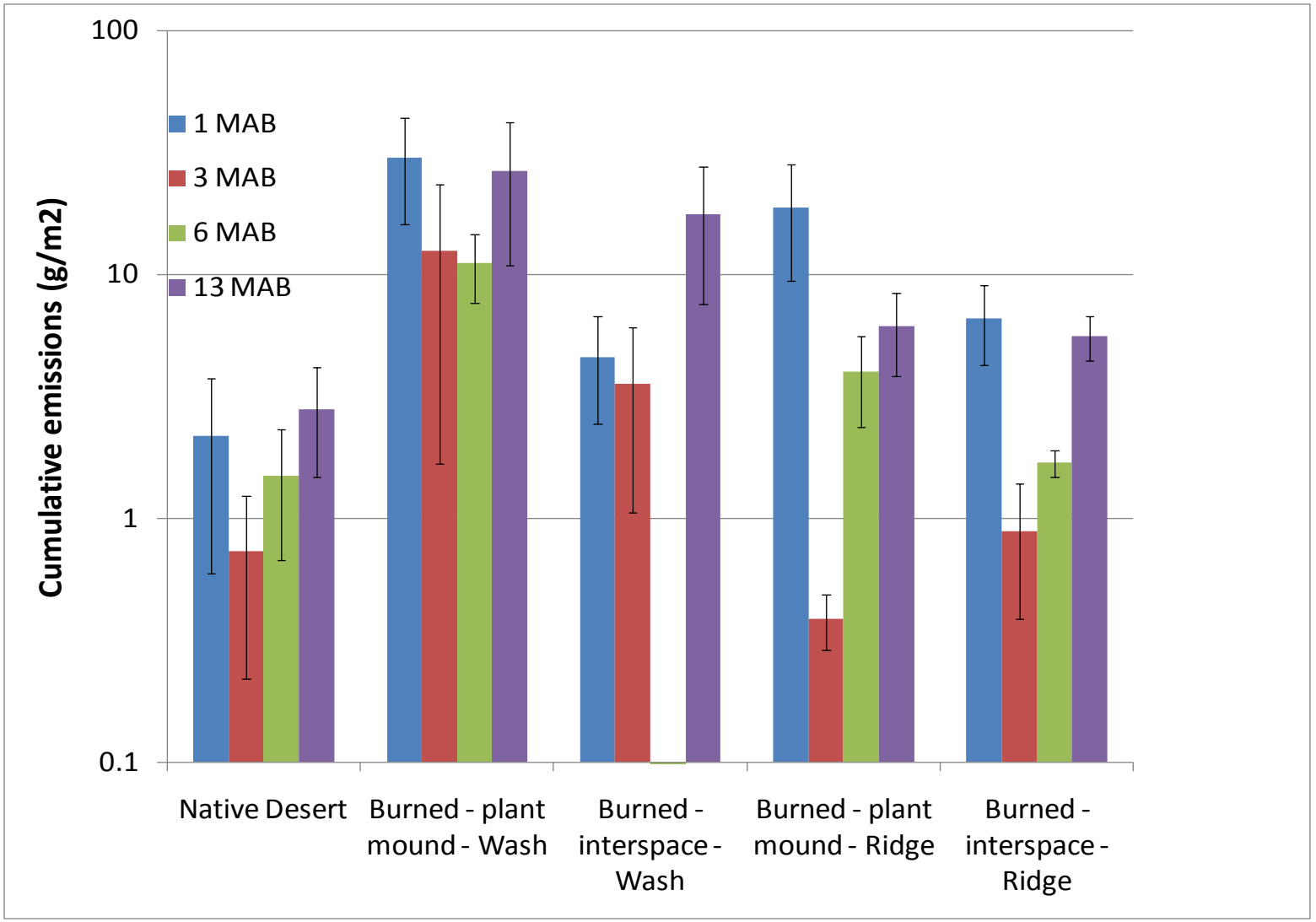
- Measure erodibility as landscape heals
- Characterize chemistry of suspended dust



Differences between surface types (e.g., 1 month after fire)

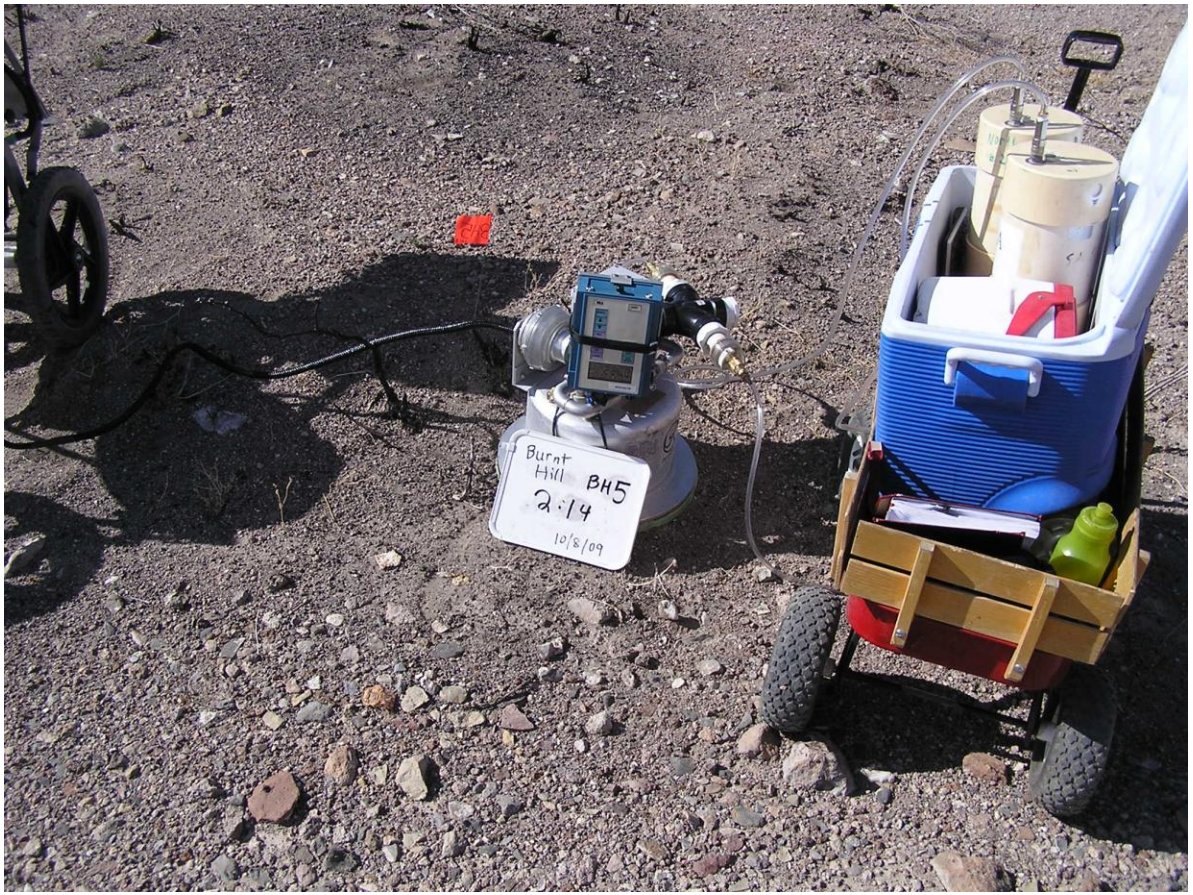


Temporal behavior



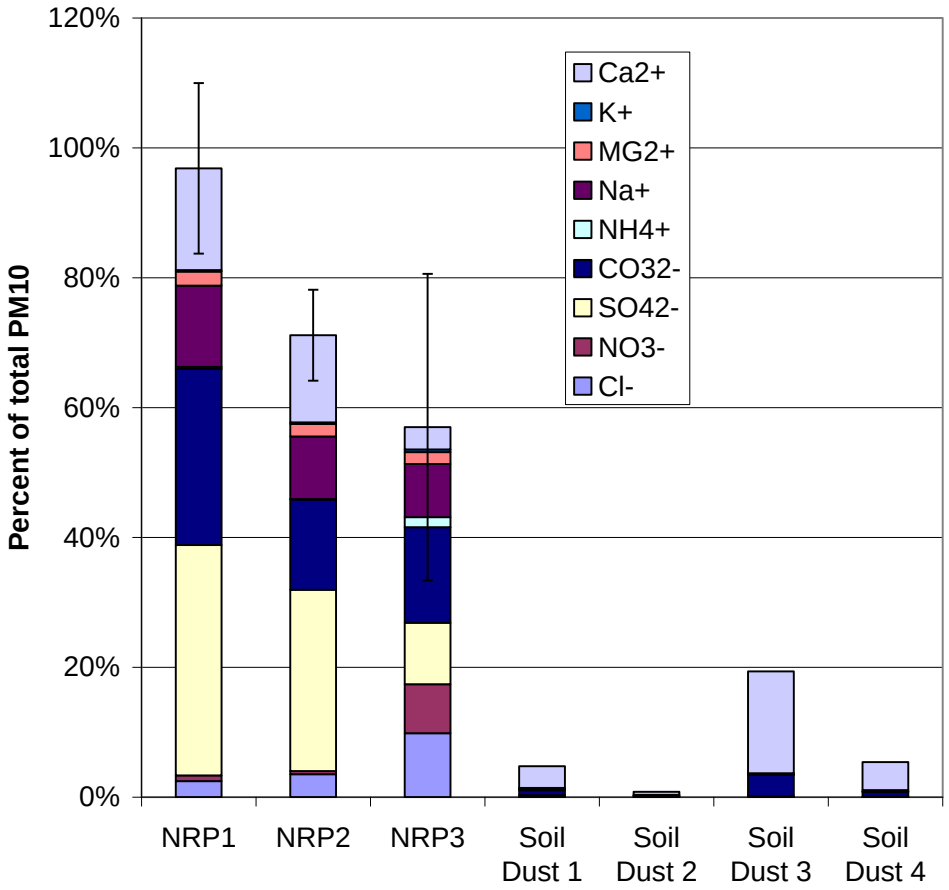
Chemical analysis of suspended material

- Attach filter or other sampler to exhaust port
- Analyze filter for specific constituent



Types of information from filter analyses

- Chemistry
- Size distribution
- morphology
- Rad activity
- Mineralogy



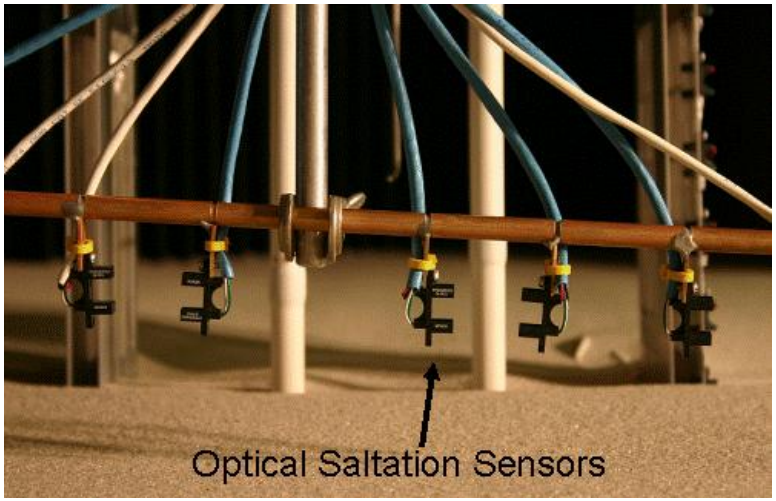
Questions?

How well does sand sensor work?

- Collocated tests with mass based trap showed excellent agreement
- There is potential for identifying the sizes of sand particles detected by the sensor

Sand movement sensors

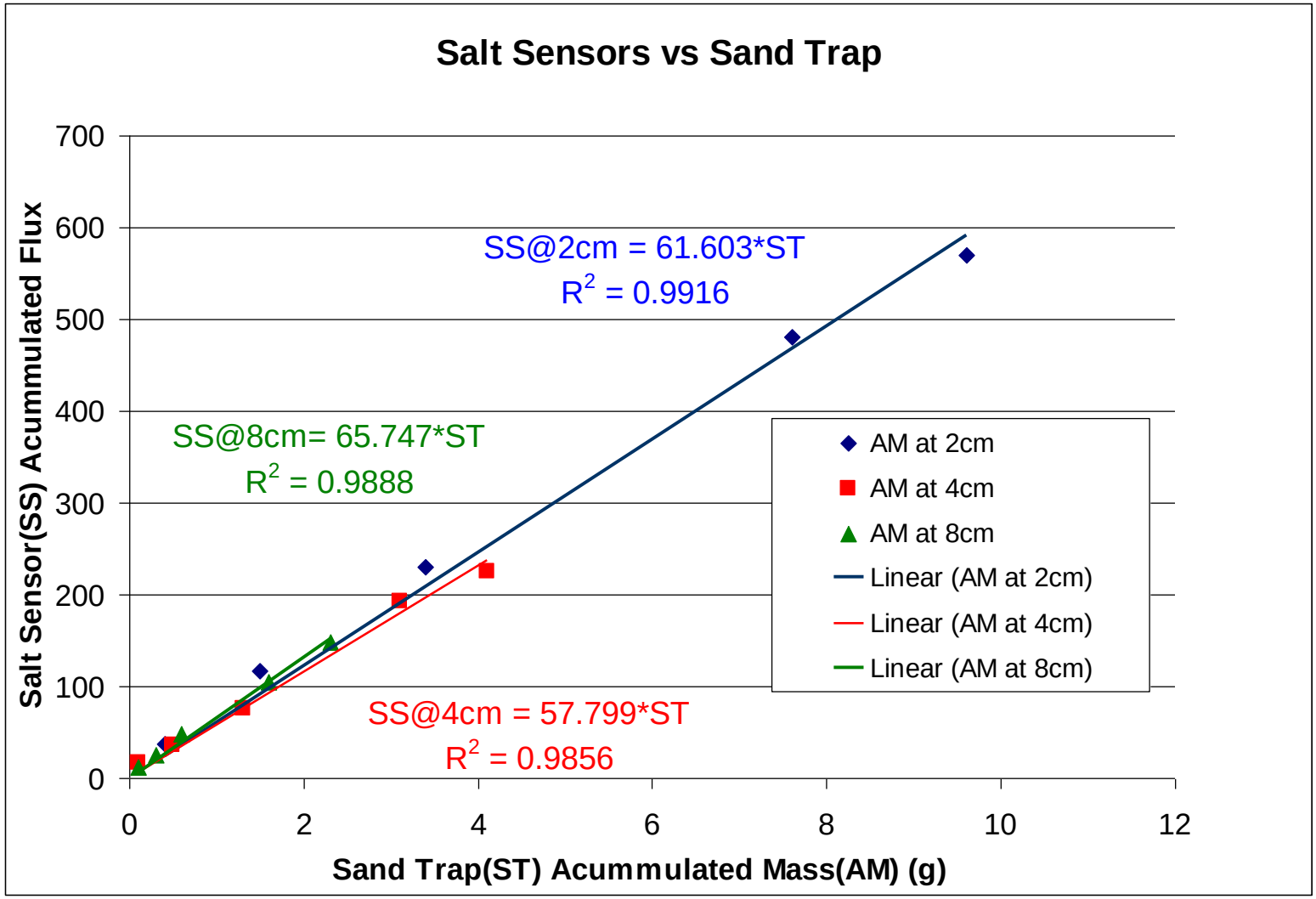
- Experimented with microphone and impact style sensors
  - Sensitivity was poor
- Opted for fast-response optical based sensors



Sand movement sensor versus bulk mass

- Collocated with sand traps at University of Guelph sediment wind tunnel
- Nominally 0.125 mm sand
- Guelph-Trent sand traps were masked off so that sand entering trap must go through optical sand movement sensor

Excellent collocation results



Some considerations

- PI-SWERL footprint small
  - How many measurements do you need to get reasonable estimate of emissions?
  - For heterogeneous surfaces, how do you pick where to measure?
  - For surfaces with vegetation or other roughness, how do you account for shear stress partitioning?
  - How do you estimate emissions (non-cumulative? Cumulative? – what averaging time do you use?)