TRACKING SOURCES OF FUGITIVE DUST AT NIPOMO MESA, CALIFORNIA

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Aeolian sand dunes can be great fun for humans, and depending on their use, can be either beneficial or detrimental to humans.

Due to increased population pressure and desires for human access to coastal environments, and the fact that coastal lands are a popular location for many human activities, coastal aeolian systems often require careful environmental management.

Off-highway vehicles (OHVs) represent a common human recreational use of dune lands, and can be a source of environmental impacts on coastal dune systems. In California, OHV use in California has quadrupled in the past 20 years.

One of the most evident environmental consequences of OHV driving on dune lands is the emission of airborne dust.

In this study, we look at high PM_{10} levels reported in the Nipomo Mesa area of San Luis Obispo County, California, and consider a possible connection to OHV use at a coastal dune field upwind of the mesa.

Geological / Environmental Setting

The Guadalupe-Nipomo dune field in Central California, which extends from the mouth of the Santa Maria River to southwest of San Luis Obispo. One of the largest coastal dune fields in California, and contains the highest coastal dunes on the USA West Coast.

Inland of the dune field is the Nipomo Mesa, a roughly triangular-shaped lobe up to ~20 km wide of stabilized, vegetated, elevated Quaternary aeolian sands on which soils have developed, bounded to the northwest and south by alluvial drainages, and to the west by the dune field. Many parts of the mesa are used for residential development, with a population of about 50,000. Parts of the mesa, and the surrounding lands, are used for agricultural fields (irrigated vegetable crops and berries), light industry, and a petroleum refinery with associated petroleum coke storage piles.

Geological / Environmental Setting

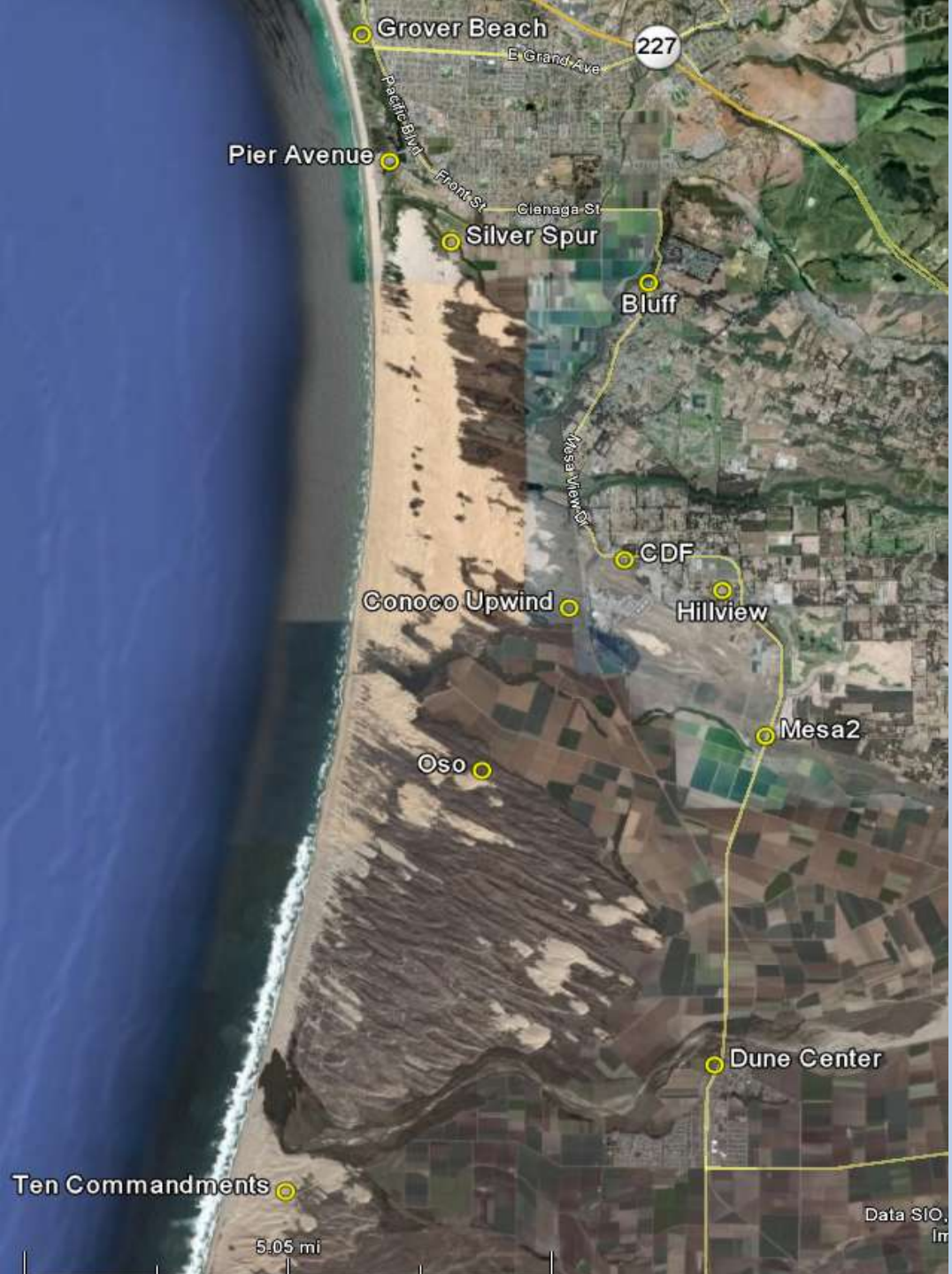
Various parts of the dune field are owned and managed by a variety of agencies, including private owners, San Luis Obispo County, the Santa Barbara County Parks Department, the Nature Conservancy, U.S. Fish and Wildlife Service, and the California Department of Parks and Recreation (California State Parks) which owns the Oceano Dunes State Vehicular Recreational Area (SVRA).

The Oceano Dunes SVRA includes a stretch of beach open for vehicle use including driving, and a portion of the sand dunes open to off-highway vehicle use, including quads, dirt-bikes, and four-wheel drive vehicles. It is the only state park in California where vehicles can be driven on the beach and the only state designated ORV area on a coastal dune complex. Total visitorship exceeds over 2 million customers per year.

Geological / Environmental Setting

Previous air monitoring studies conducted by the San Luis Obispo County Air Pollution Control District (SLOAPCD) documented higher concentrations of airborne particulate matter on the Nipomo Mesa compared to other portions of San Luis Obispo County and other coastal regions of California, such that the California state PM_{10} standard has been exceeded at one site or more on the Nipomo Mesa on >¼ of sampled days. During the particulate episodes, the aerosols were comprised of crustal materials, and the wind direction was from the direction of the coastal dune field onshore onto the mesa.

This study was designed to further evaluate the nature and origin of the particulate matter impacting the Nipomo Mesa and to evaluate their potential sources including OHV activity in the SVRA.



THE STUDY

Aerosols and sediments were sampled at a variety of sites on the mesa, on the dunes, and downwind of industrial and agricultural areas. Sites included within and downwind of the dunes at the SVRA as well as within and downwind of undisturbed dunes north and south of the SVRA.

Measurements were taken during short-term, high-wind events as well as prolonged periods from early 2008 into early 2009.

THE STUDY

DRUM three-stage or eight-stage impactor aerosol samplers were deployed at various times at the sites, allowing identification of aerosol mass, size, and composition at and between sites downwind from the SVRA, downwind from dune areas without OHV activity, as well as downwind from potential agricultural and industrial dust sources.

The DRUM sampler collects aerosols on strips in each size stage, with an approximate 3-hour time resolution that facilitated correlation with the local meteorology. The DRUM samples, therefore, provided continuous measurements of the size-resolved (either three or eight size fractions) aerosol mass and/or elemental composition with three-hour time resolution for up to six weeks.

BSNE traps were used to capture moving aeolian sands for measuring the fluxes and characteristics of saltating particles in the dune region.

THE STUDY

Samples of surface soil were collected along prevailing wind transects from each air sampler site back to the ocean, with documentation of land cover and soil surface condition (specifically, the presence or absence of crusts) taken at every sampling site.

Soil samples were dry-sieved into various size fractions.

Subsets of the soil samples were analyzed for grain size by laser diffraction after pretreatment with sodium hexametaphospate as well as for their dry aggregate size distribution.

The samples shown to have the highest silt and clay fractions (relatively) were resuspended via an air jet into an 8-stage DRUM impactor.

The aerosol deposits on the DRUM strips were quantitatively analyzed for time-resolved mass in each size cut via beta gauge.

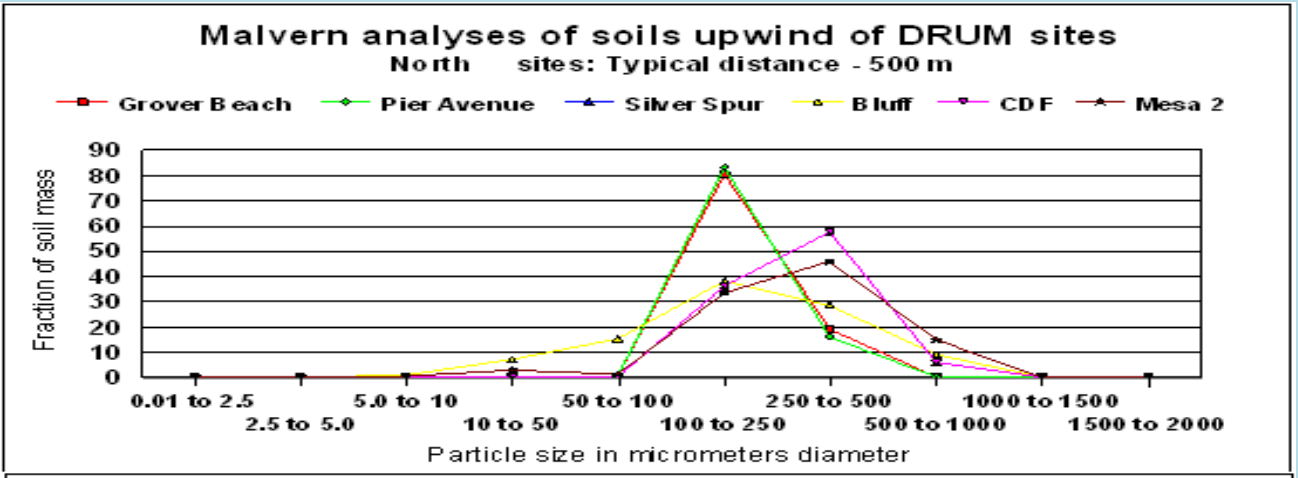
Some of the aerosol samples were analyzed for elemental composition by synchrotron X-ray fluorescence at Lawrence Berkeley National Laboratory.

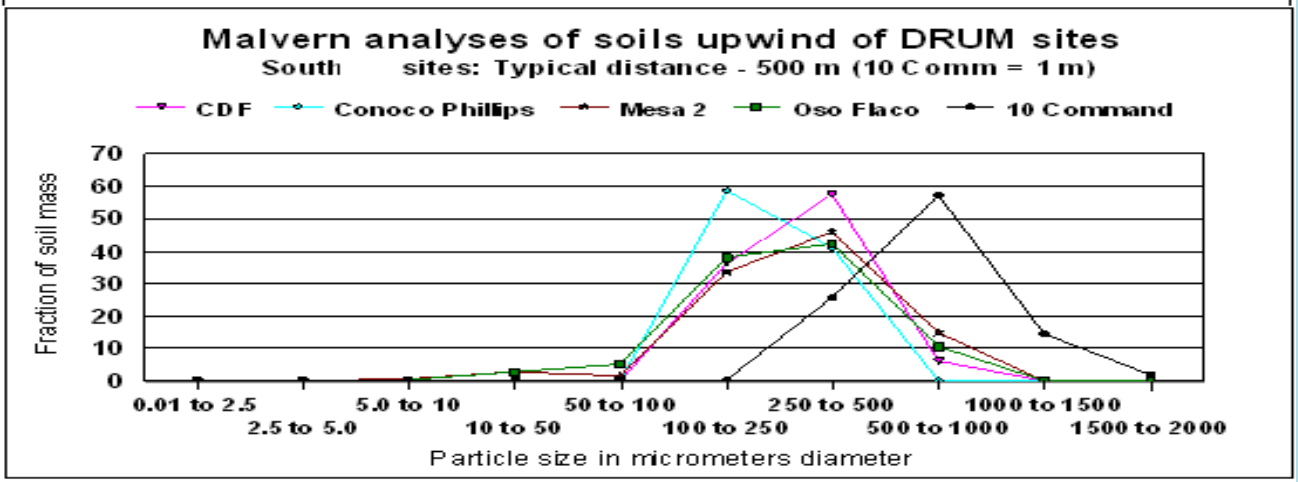
RESULTS

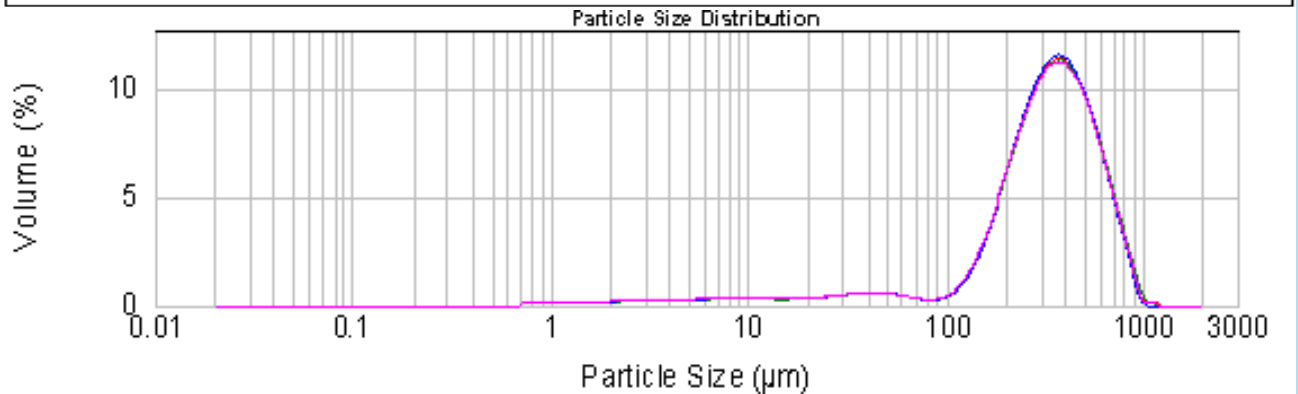
The Oso Flaco site lies in a protected natural dune area downwind of an extensive sand sheet that has never been open to vehicular traffic. At this site, and upwind on the sand sheet, a weak but intact crust about 1 to 2 cm thick was on the surface of the sand.

The crust was was not observed at any of the sites investigated in the SVRA.

RESULTS

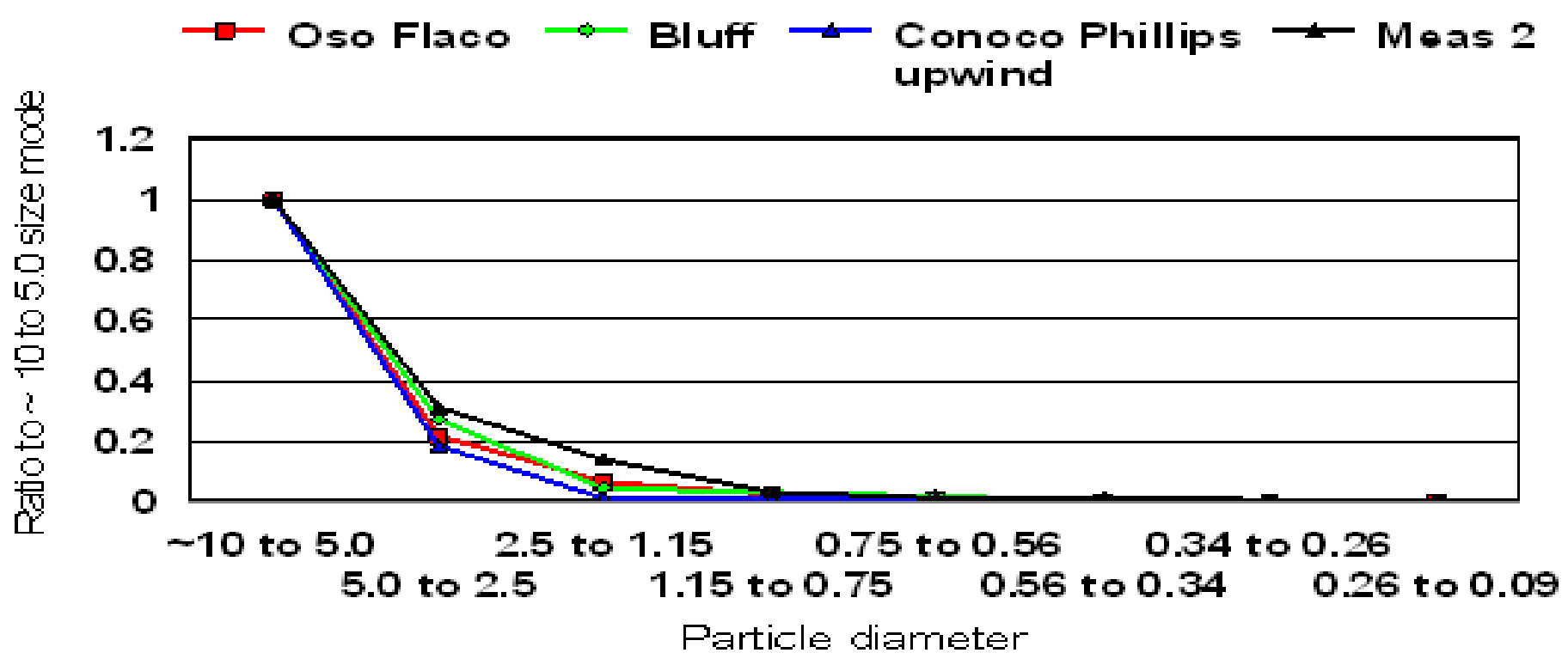






The soil texture of samples from the dune areas was sand, dominated by fine to medium sand grains, although most sites showed a minor but consistent presence of silt-sized grains, and some sites showed traces of clays and grains as small as 1 micron or finer.

RESULTS

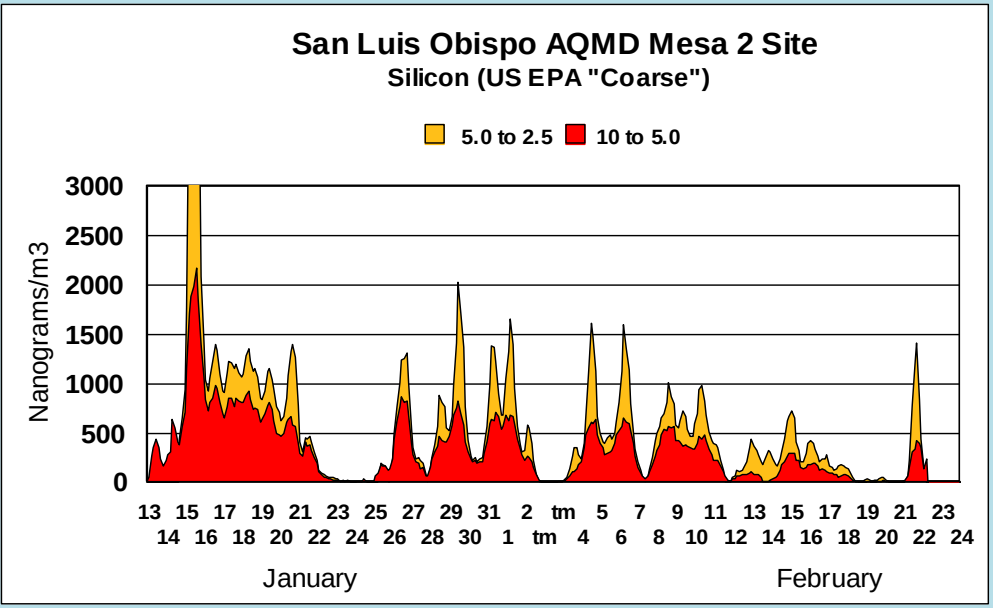


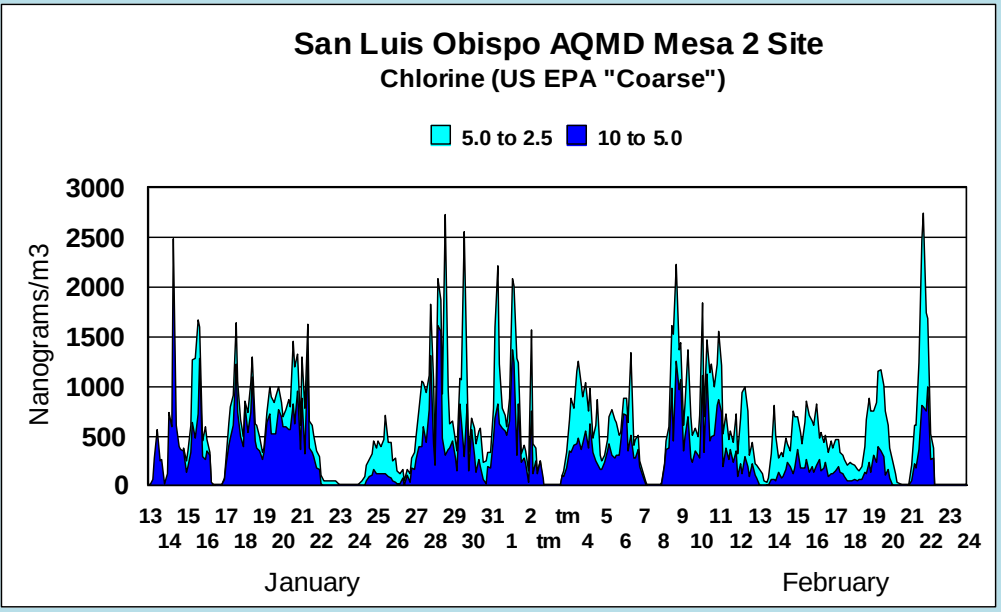
Analyses of the soil samples that were resuspended into a DRUM sampler did show that there is indeed a small fraction of the soil at some of the sites with particle diameters less than 10 microns.

The relative proportions of the particles in the different size stages of the DRUM was similar to the particle size proportions shown by the laser diffraction analysis.

Elemental analysis of the re-suspended soils showed very similar compositions between the soil samples at the different sites.

RESULTS



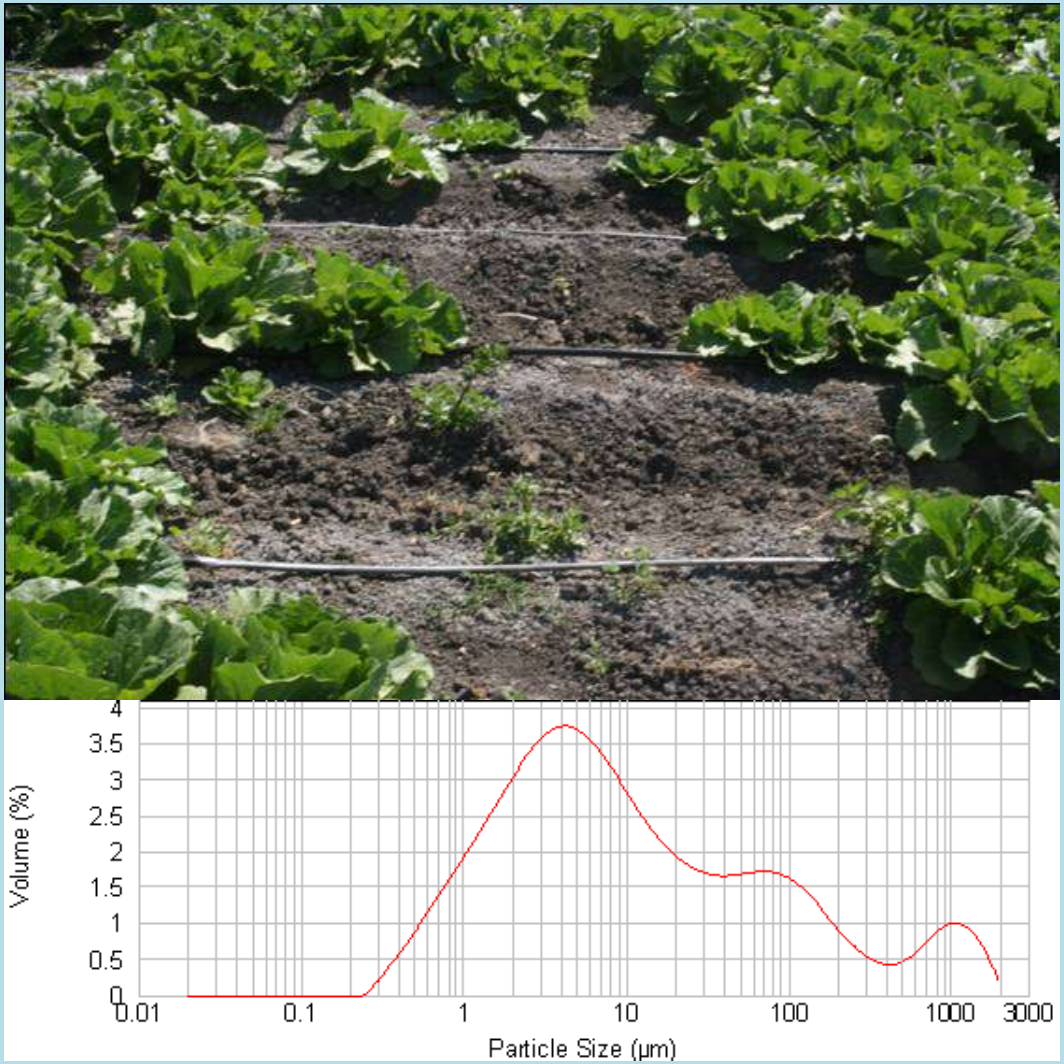


Aerosol mass was generally dominated by coarse particles (2.5 μm to 10 μm).

Aerosol composition, especially at sites downwind of the dune field, was dominated by silicon, with smaller amounts of chlorine- a sea salt tracer.

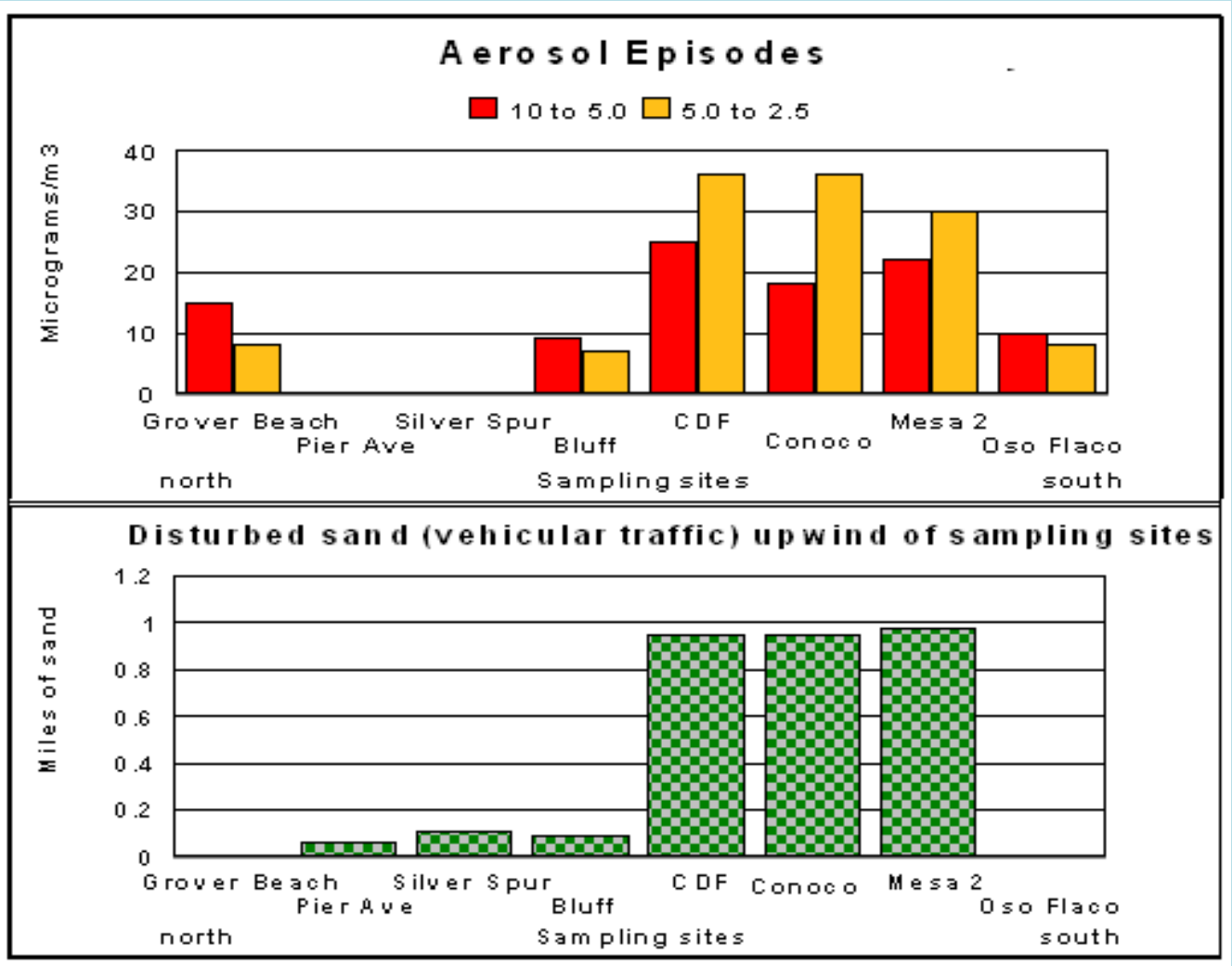
The Cl to Si ratio varied with weather and season. During dry periods, the ratio of chlorine to silicon was on the order of 10%. During rain events in the winter when the dunes were wetted, the average ratio of chlorine to silicon was on the order of 25%, with some episodes dominated by chlorine and almost no silicon or soil-related elements.

RESULTS



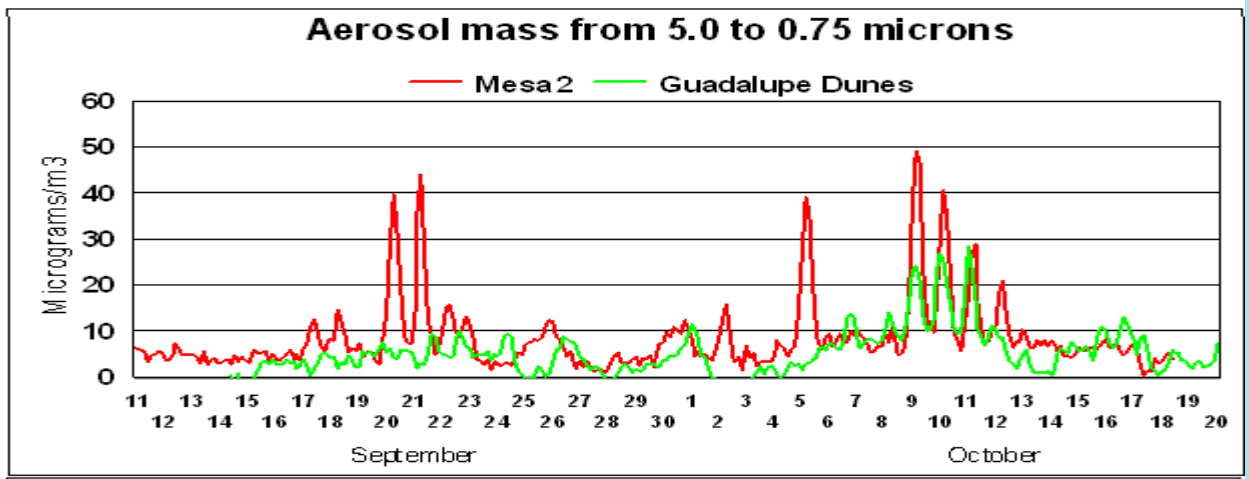
The agricultural soils were clay loams to silty clay loams that showed no indication of being highly wind erodible, and unlike the sites downwind of the dunes, there was a near-total lack of episodes of high PM10 concentrations during wind events at the Bluff sampling site downwind of the farmed area.

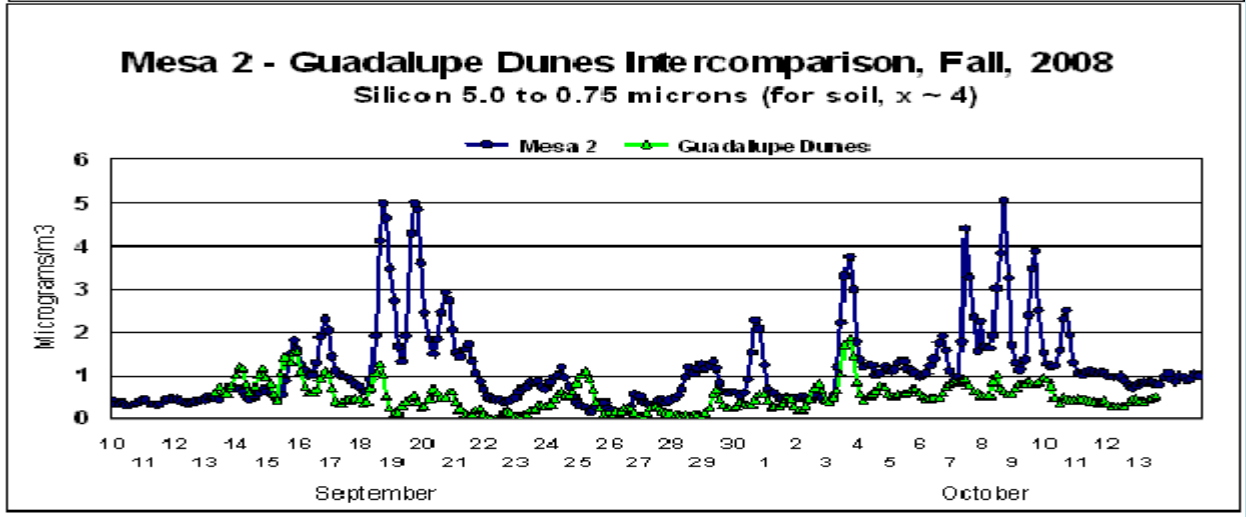
RESULTS



Aerosol concentrations in different size fractions were much higher at sites downwind of the SVRA (CDF, Mesa 2, and Conoco) than at the other sites where no vehicle activity is allowed. There was a positive correlation between aerosol concentrations measured at each site during wind episodes and the amount of unvegetated disturbed sand upwind of each site.

RESULTS





We can look at a comparison between the Mesa 2 site, downwind of the off-highway vehicle area, and the Guadalupe Dunes site, the same distance downwind of a generally undisturbed stretch of the dunes. PM levels at Mesa 2 were much higher during wind episodes, as was the mass of silicon. These and other results suggest that dust levels were lower downwind of undisturbed sands compared to sites downwind from where the dune soils were disturbed.

SUMMARY

Several lines of evidence suggest a potential source of elevated dust particulate matter levels at the Nipomo Mesa.

The dune sands showed the presence of a small but consistent component of particles as fine as very fine silt or clay, and aerosol episodes were detected downwind of the dune field.

The properties of the alluvial agricultural soils indicated low wind erodibility, and there was a near-total lack of aerosol episodes downwind of the croplands.

Surface crusts were observed on many of the undisturbed sands in the dune field, but not at the investigated parts of the SVRA.

Aerosol concentrations generally correlated with the amount of open, disturbed sand upwind of each site: thus, aerosol concentrations were higher at sites downwind of the SVRA than at sites downwind of undisturbed dunes.

Aerosol compositions were dominated by silica. Lower total aerosol mass, higher proportions of sea salt and lower soil element concentrations were found in aerosols downwind of undisturbed sands compared to sites downwind of disturbed dunes.

CONCLUSIONS

It appears to us that the coastal aeolian sand deposits, especially where they have been anthropogenically disturbed, are a main source of the dusts impacting the Nipomo Mesa.

Wind erosion and fugitive dust emission could be reduced by increasing vegetation cover on or downwind of the dunes, especially where they have been disturbed, using engineering approaches to trap and stabilize moving sand, and/or by reducing human disturbance of the dune field.

Acknowledgements

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