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Agriculture and Natural Resources | California Institute for Water Resources

Characterizing the Impact of Salton Sea Water Management and Restoration Practices on Regional Air Quality

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Project Summary

Salton Sea is a highly saline and eutrophic lake in Southern California which has served as a natural habitat for wildlife during the past century. With the increased imbalance between evaporation and water input to the lake, driven by water conservation, recycling, and transfers, water in shallow areas of the Sea is receding, exposing the playa underneath. Newly exposed playa has become a concern as an additional source for dust emissions in an air basin that is currently an area of non-attainment considering California and National Ambient Air Quality standards for particulate matter. In 2013, a comprehensive document on Monitoring and Assessment Plan of Salton Sea Ecosystem Restoration Program was developed by a team from California Department of Water Resources, California Department of Fish and Wildlife, U.S. Bureau of Reclamation, U.S. Geological Survey, and academia.

A report from a Focused Technical Group on air quality, highlighting air quality monitoring plans for the area as well as air quality questions and information needs, was also included in the document. This group identified chemical characteristics of suspended dust particles at Salton Sea as one of the critical information needs to answer the question of current air quality conditions at the Sea. Without chemical characterization of the airborne particles, it is difficult to assess the impact of particulate emissions from Salton Sea and the playa under current conditions, to address the potential effects on human health and agricultural crops at downwind receptor sites, and to identify areas where further actions to reduce dust emissions are needed.

In this work, we propose to conduct measurements of aerosol composition, by offline chemical analysis of particles collected onto filter samples, in different size bins, ranging from <0.1 μm to 10 μm. Measurements will be conducted at Salton City, located on the southwestern shore of Salton Sea, and in different seasons to determine the impact of temperature and humidity fluctuations on contribution of playa dust emissions to airborne particles. Results of our measurements will provide a baseline for chemical characteristics of dust emissions in the area and are valuable to understand the impact of current water management practices on emissions of trace elements and salt from Salton Sea, to examine the effectiveness of current mitigation practices, and to identify other areas where new mitigation and water management practices might be needed to reduce emissions of potentially harmful elements.

Introduction

Air quality of the Salton Sea Air Basin, which includes parts of the South Coast Air Quality Management District (AQMD) (i.e., Riverside County) and the Imperial County Air Pollution Control District (APCD) (i.e., Imperial County) is affected by pollution transported from large urban and industrial areas upwind (e.g., Long Beach and Los Angeles, CA and Mexicali, Mexico), emissions from agricultural activities in the basin, and emissions from Salton Sea and its shorelines. Salton Sea, a saline and euotrophic lake, has been a valuable ecosystem for local and migrating birds and various types of fish populations. Agricultural activities in the basin are the main factors controlling sustainability of the lake since agricultural drainage and return flows serve as the primary inflow to the Salton Sea.

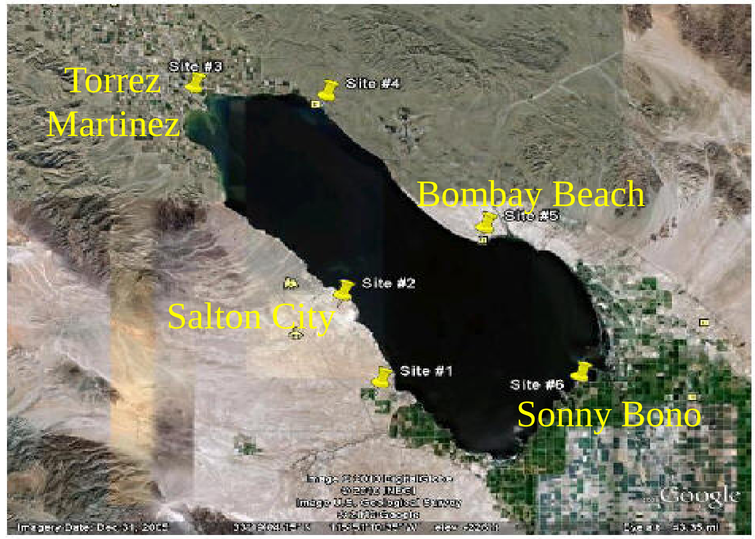

Figure 1. Geographical location of current monitoring stations around Salton Sea.

The water quality of the runoffs thus also directly impact the lake's water quality [*LeBlanc and Kuivila*, 2008; *LeBlanc and Shroeder*, 2008; *Vogl and Henry*, 2002] and species' habitat. Recently with the imbalance between water input to the lake and evaporation, water levels in the lake have started to decrease, resulting in exposing the playa on the shoreline along the shallower parts of the lake. This creates an additional source for aerosolizing dust and salt, similar to what has been observed around Owens Lake, in an air basin which already exceeds the state-level for PM_{10} (particulate matter smaller than 10 micron in size) on numerous days (e.g., 207 exceedance days in 2009 for State-level PM_{10}, http://www.water.ca.gov/saltonsea/habitat/eir2011.cfm) [*Buck et al.*, 2011; *King et al.*, 2011].

During the last decade, efforts have been focused to restore the ecosystem at Salton Sea, with some attention given to the effects these restoration activities and outcome would have on the water and air quality at Salton Sea. An air quality monitoring network was established around Salton Sea that provides meteorological data (temperature, relative humidity, wind speed and direction) and $PM_{2.5}$ (particles less than 2.5 micron in size) and PM_{10} mass concentration since 2010 (http://imperialcounty.net/AirPollution/web%20pages/salton%20sea.htm). These data indicate that PM_{10} mass concentrations at Bombay Beach, located on the northern side of the Salton Sea, was the lowest compared to the mass concentrations observed at the north-western (Torres Martinez), south-western (Salton City), and south-eastern (Sonny Bono) sites.

An important factor missing in the current air quality measurements at Salton Sea is the composition of the suspended particles. Chemical nature of dust particles can impact human health [e.g., *Plumlee and Ziegler*, 2003; *Ross et al.*, 1996; *Sheppard et al.*, 2006] and nutrient- and pollutant-level of ecosystems (including agricultural fields) downwind of the sources [e.g., *Reynolds et al.*, 2006; *Swap et al.*, 1992]. Previous work has shown that heavy metals such as cadmium , copper, molybdenum, nickel, zinc, and selenium are elevated in the sediments at the Salton Sea [*Vogl and Henry*, 2002]. With high salinity of the Salton Sea water, salt concentrations on dust particles originating from its shorelines are expected to be high as well. Characterizing the airborne concentrations of trace metals and salt components is critical since these particles can have adverse effects on human health as well as crops once transported to receptor areas downwind of the sea.

Wind speed has a significant effect on generating airborne dust in arid areas. Based on the meteorological data obtained from the Salton Sea monitoring network, wind intensity around Salton Sea shows seasonal variability. Although the degree of seasonal variability is different at different sites, higher wind speed values are observed during spring (Mar-May) at all sites. Higher springtime wind speed at Salton City corresponds to episodically higher PM_{10} concentrations at the site (Figure 2). PM_{10} levels at Sonny Bono and Torres Martinez appear to be independent from local wind speed and peak during summer (Jul-Sep) months. Winter values of PM_{10} at all sites are lower than the peak values during spring or summer (Salton City example shown in Figure 2). A recent study observed an increase in the potential for dust emissions from playa-like areas around Salton Sea in winter due to weakening of salt crusts under cooler and more humid conditions compared to summer or spring [*King et al.*, 2011]. Contribution of playa dust to total PM_{10} is yet to be determined.

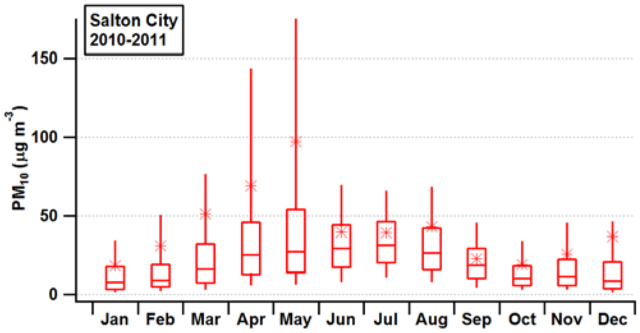

Figure 2. Monthly statistics on PM_{10} concentrations measured at Salton City (mean values are shown by asterisk while box and whiskers show 10th, 25th, 50th, 75th, and 90th percentiles).

Although data from the Salton Sea Monitoring Network provides some input to assess the impact of particulate matter in the area, there are scientific gaps in the data that curtail progress towards a better understanding of the airshed /watershed interactions in this region. For example, as eluded to above, there are no measurements of chemical composition of PM_{10} or $PM_{2.5}$ particles. The Air Quality Focused Technical Group from the team of experts preparing the Monitoring and Assessment Plan for Salton Sea Ecosystem Restoration Program identified chemical speciation of the particulate matter at Salton Sea as one of the key information needs to answer the air quality conditions at Salton Sea [*Case III et al.*, 2013]. Such detailed chemical measurements are needed to understand the effects of restoration activities, natural lake emissions, and future water management practices on the regional air quality.

In this work, we propose to perform size-dependent measurements of PM_{10} in order to determine the concentration of heavy metals, salts, and crustal elements in airborne particles. By providing a baseline dataset on aerosol composition as well as filling the gaps of current air quality- related data from Salton Sea measurement network, results from this work will support both objectives of the Air-Quality Monitoring plan highlighted in the document on Salton Sea Ecosystem Monitoring and Assessment Plan[*Case III et al.*, 2013].

Research Program

Methods

As mentioned above, PM_{10} mass concentrations at Salton City is higher than at Torres Martinez or Bombay Beach. Furthermore, previous dust emissivity measurements indicate that the playa at the southeastern edge (close to Sony Bono), northern edge (close to Bombay Beach), and northwestern edge (close to Torres Martinez) have higher tendencies for dust generation due to presence of soft-salt crust, especially during winter months [*Buck et al.*, 2011; *King et al.*, 2011]. Considering the prominent seasonal wind direction around Salton Sea (Figure 3), to capture the effects of emissions from playa and dry wash around the sea, we plan on performing measurements at Salton City where auxiliary measurements of meteorological parameters and total mass concentration of $PM_{2.5}$ and PM_{10} are also available. Figure 3 displays the seasonal relation between PM_{10} mass and wind direction at Salton City (2010-2011 data, http://imperialcounty.net/AirPollution).

It is apparent that at this location wind patterns during summer months are most notably different than the rest of the year. To capture the influence of variability in wind direction on PM_{10} composition and concentrations, we propose to perform measurements at Salton City during summer (August- September) and winter (January-February). The exact timing of sampling during each season depends on logistical constraints at the sites and is to be determined at a later time in coordination with California Air Resources Board, Imperial Irrigation District, and/or Imperial County Air Pollution Control District. In order to gain more insights into the composition of aerosol particles at Salton Sea, a Micro Orifice Uniform Deposition Impactor (MOUDI) will be used to collect size-fractionated (10 total size bins, covering coarse and fine modes) aerosol particles. Because filter samples provide characteristics of ensemble of particles collected during the sampling period, it is most ideal to collect samples during periods with consistent influence of a source region. Average diurnal wind direction at Salton City show a distinct and consistent diurnal pattern in wind direction. Based on these profiles, we propose to collect filter samples twice daily, i.e., during daytime and nighttime.

Aerosol particles will be collected on Teflon filters (47 mm in diameter and a pore size of 2.0 μm), at a flow rate of 30 lpm, and in 10 different stages of the MOUDI, corresponding to a size range of <0.1 μm to 10 μm. Filter substrates will be stored in the freezer before preparation for analysis. To increase signal level of some of the tracer species, filter samples from 2 consecutive stages will be combined for analysis, resulting in species concentrations in 5 size bins (< 0.1 μm, 0.1-0.32 μm, 0.32- 1 μm, 1-3.2 μm, and 3.2-10 μm). Each substrate will be weighed by a micro balance at controlled temperature and relative humidity before and after sampling to measure the mass of collected particles. Samples will be extracted by water first and then treated with a mixture of inorganic acids in a microwave digestion unit for elemental analysis (sodium, calcium, magnesium, barium, potassium, aluminum, iron, silicon, titanium, zinc, copper, manganese, tin, nickel, cobalt, chromium, lead, vanadium, arsenic, selenium, and cadmium) by inductively coupled plasma mass spectrometry (ICP-MS). Blank filters will be collected before and after each sampling period to determine proper background subtractions. Depth-dependent (surface down to ~30 cm) samples of sand, soil, dry wash, and playa from areas around Salton Sea (including Salton

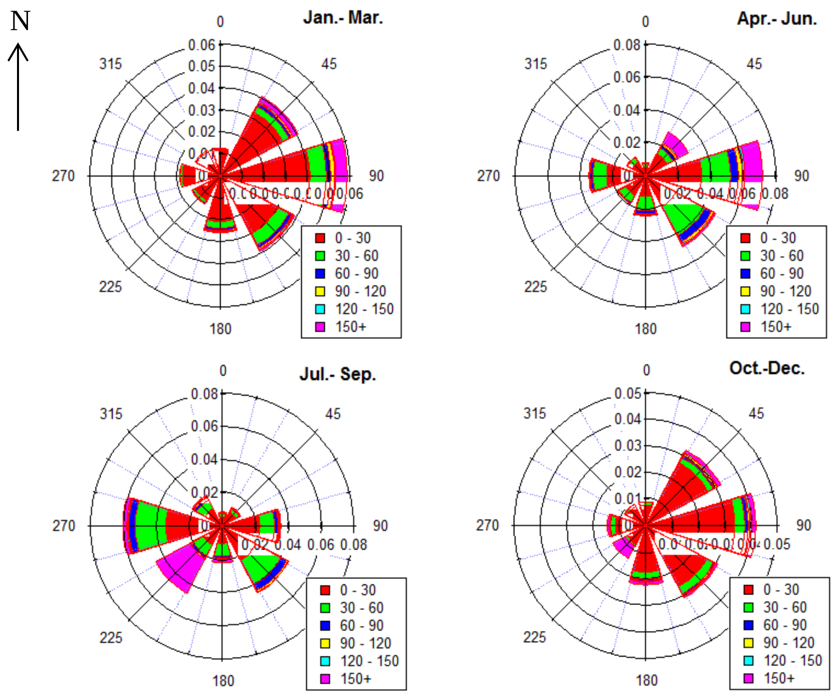

Figure 3. Seasonal wind roses, colored with PM_{10} mass concentration (in μg/m^3) measured at Salton City (2010-2011).

City and Sony Bono) will also be collected and analyzed by ICP-MS to obtain chemical characteristics of the areas that could act as potential aerosol sources.

Enrichment factors (Equation. 1) of several species will be calculated to compare the atmospheric ratios of specific elements with respect to aluminum (or iron) to the corresponding crustal ratios [*Galloway et al.*, 1982; *Reheis et al.*, 2002; *Reheis et al.*, 2009; *Reynolds et al.*, 2006]:

$$Enrichment\ Factor = \frac{\left(\frac{[element]}{[Al]}\right)_{air}}{\left(\frac{[element]}{[Al]}\right)_{crust}} \quad (1)$$

In general, atmospheric enrichment of an element (i.e., enrichment factor > 1) will indicate a non-crustal source for that element. Specifically, samples that show enrichment in salt components (e.g., sodium and magnesium) will indicate a strong source signature of playa and/or sea-salt from the Salton Sea itself [*King et al.*, 2011]. Because of the high concentrations of selenium in the irrigation waters around Salton Sea as well as in its sediments, enhancements in atmospheric selenium will indicate emissions from playa or agricultural sites in the area. Wind direction and inter-variability among the different elements will then be used to constrain the contribution from different sources with a similar signature. For example, co-variability of selenium with sodium will confirm a source contribution from the playa whereas co-variability of selenium and crustal materials like iron will indicate contributions from agricultural dust. Enrichments in chromium, nickel, copper, vanadium, and zinc will indicate effects from industrial and vehicular emissions [e.g., *Kim et al.*, 2000; *Singh et al.*, 2002].

Aerosol sampling at Salton City will be performed during summer (August- September) and winter (January-February), for 7 days during each season. Surface dust, dry wash, and playa samples will be collected before summertime aerosol sampling, as early as in March 2015, and protocols for analysis will be developed.

Notable Achievements

Due to the lack of data on chemical nature of suspended dust particles around Salton Sea, this work will serve as the baseline to which future measurements in the area can be compared. Results on concentration of trace metals and salt components will be critical in assessing the current impact of dust emissions from the Sea and its playa on human health and sustainability of agricultural crops in areas located downwind of Salton Sea. Measurements of trace metals in the playa around Salton Sea will also help in identifying areas where future restoration and mitigation practices might need to be focused on to reduce airborne concentration of such species.

Results from this study will be summarized in a manuscript (e.g., *Environmental Science and Technology*, *J. of Geophysical Research*, or *Geophysical Research Letters*) and presented to the scientific community at regional and/or national meetings (e.g., American Geophysical Union or American Association for Aerosol Research). Furthermore, study findings will be shared with Imperial County Air Pollution Control District, California Air Resources Board, and/or Imperial Irrigation District.