Aeolian Research 33 (2018) 82–92

Contents lists available at ScienceDirect

Aeolian Research

journal homepage: www.elsevier.com/locate/aeolia

Projected changes in dust emissions and regional air quality due to the shrinking Salton Sea

Sagar P. Parajuli[a,*], Charles S. Zender[b]

[a] King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia
[b] Department of Earth System Science, University of California, Irvine, CA, USA

ABSTRACT

The Salton Sea lake level in California is expected to transition in 2018 from a period of gradual decline to a new era of rapid decline that will expose about 40% of the year 2000 lakebed to wind erosion by 2030. The newly exposed Playa substrate can emit large amounts of particulate matter (PM) and thus degrade regional air quality. We use the Weather Research Forecast model (WRF-Chem) to estimate changes in dust aerosol emission and distribution in the Salton Sea region from 2000 to 2030. First, we evaluate simulations of present day wind speed, mineral dust emission, concentration, and optical depth over the region. WRF-Chem at 4 km spatial resolution satisfactorily reproduces the present-day spatio-temporal pattern of dust emission. With an estimated 38% exposure of the Salton Sea by 2030, the domain-averaged PM10 in the 2 × 2 degree domain enclosing the Sea increases on average by 11% and by nearly a factor of ten in localized source areas. The simulated increases in dust emission are consistent with earlier empirical estimates although our estimates are comparatively lower. Our regional model provides more spatially detailed and quantitative attribution of the projected air quality degradation. For example, our model suggests that newly exposed playa emissions will emanate more from the southwest than southeast side of the lake, even though most of the new playa will be on the southeast side. These results may inform decisions that affect trade-offs between environmental quality, human health, and water-use issues in the Salton Sea region.

1. Introduction

The Salton Sea is a saline lake in the Imperial and Coachella Valleys in California that was formed by accidental flooding in 1905. Continuous shrinking of the Sea has raised concern for air quality in southern California, including the nearby counties of Riverside, Imperial, and San Diego (Cohen, 2014). A recent water transfer deal, the Quantification Settlement Agreement (QSA), made among the Imperial irrigation district, San Diego County Water Authority, and several other agencies, will accelerate shrinking of the Salton Sea beginning in 2018 (QSA, 2003). Dust deflation from other anthropogenically exposed playas, such as Owens Dry Lake in California and multiple lakes in Central Eurasia, produced severe particulate air quality related issues for local and downwind communities and viewsheds (e.g., Reheis, 1997; Gillette et al., 1997; Kellogg and Griffin, 2006) before the advent of first global then regional dust forecast modeling (e.g., Tegen and Fung, 1994; Zender et al., 2003). We apply such quantitative techniques to project changes in the Salton Sea regional air quality, and to provide a baseline of outcomes expected from current policy.

The Salton Sea region has large topographic variation and it is a complex region to model. Lying in a large valley, the surrounding topography of the Salton Sea strongly controls local circulations. High-resolution modeling is thus essential in capturing the spatio-temporal variability of the meteorology that affects the air quality of the region. WRF (Weather Research and Forecasting) is a latest mesoscale weather forecast model with several options for atmospheric processes (Skamarock et al., 2005). The chemistry module (WRF–Chem) extends WRF by incorporating a chemistry module that interactively simulates atmospheric aerosols and gases including their mixing/transport and chemical/microphysical transformations (Grell et al., 2005). One of the main capability of WRF-Chem is to simulate the mineral dust cycle. Various dust modules are available in WRF-Chem with some variation in the treatment of emission, transport, and deposition. In and downwind of many dry regions of the world, dust is the main constituent of air pollution (e.g., Prospero, 1999). Dust generation is mainly a regional phenomenon and so it can be best studied using WRF-Chem by running the model at a relatively high resolution.

Various studies have evaluated different dust modules of WRF-

* Corresponding author.
E-mail address: psagar@utexas.edu (S.P. Parajuli).

https://doi.org/10.1016/j.aeolia.2018.05.004
Received 9 January 2018; Received in revised form 28 May 2018; Accepted 31 May 2018

Chem and found mixed results (e.g., Shaw et al., 2008; Darmenova et al. 2009; Zhao et al., 2010; Kang et al., 2011). However, since WRF is a regional model, results of model evaluation are generally applicable to the specific region and time frame so the model must be tested in the specific region of interest before applying the model for air quality monitoring and forecasting. In this study, first we briefly evaluate the model performance in terms of simulating surface winds and dust aerosol properties before using it to estimate the emissions from the Salton Sea. We use station-measured wind and PM10 data from multiple stations and satellite AOD data for the evaluation of the simulations.

In the next few years, the amount of water flowing into the Salton Sea will decrease by about 40% and the shrinking lake will expose several square miles of lake bottom and will likely worsen the regional air quality (Cohen, 2014). The exposed lake bottom mainly constitutes playa which is a key contributing factor of particulate matter (PM) in the Salton Sea area (Frie et al., 2017). In this context, we estimate the change in dust emission and PM10 using WRF-Chem under a scenario in which dust emission is allowed from the lakebed exposed by the shrinking Salton Sea.

2. Data and methods

2.1. Modeling with WRF-Chem

Fig. 1 shows the overview of the study area in California. WRF-Chem model simulations were conducted on a single 2 × 2 degree domain outlined by the red box in Fig. 1, which includes part of Mexico. Fig. 1 also shows the location of two nearby cities chosen for a more detailed analysis of PM10. We use WRF-Chem version 3.8.1 (Grell et al., 2005) in this study. For calculation of dust emissions, we use the most commonly used dust scheme developed by United States Air Force Weather Agency (AFWA). The AFWA dust scheme follows the Global Ozone Chemistry Aerosol Radiation and Transport (GOCART) dust emission (Ginoux et al., 2001) scheme modified to include saltation and made suitable for high-resolution simulations (Jones et al., 2011). The scheme includes many aspects of the dust emissions and contrains as parameterized by Marticorena and Bergametti (1995), and more details can be found in (Cremades et al., 2017).

The details of the physics and chemistry options used in this study are given in Table 1. Because our interest is on quantifying dust emission from the Salton Sea region, we turn-off emission of all other aerosol types. We allow aerosol-radiation direct/indirect feedback so that the simulations represent real-world conditions. Many dust events in the region are associated with synoptic cold fronts that cause high winds and dust emissions (e.g., Tong et al., 2017). Therefore, the use of accurate boundary condition data is important to capture such regional weather features. Considering our high-resolution simulations, we used NCEP North American Mesoscale (NAM) Analysis (Janjic, 2003; NCEP NAM, 2015), which is one of the highest resolution boundary conditions data available for North America. NCEP NAM analysis is a dynamically consistent dataset available at high-resolution (~12km) every 6 hours. We tested the effectiveness of nudging in our initial simulations using grid nudging and surface nudging options. However, these nudging options did not improve the representation of surface winds as compared to station winds over the study area. So we did not apply nudging in this study.

Model simulations were performed at 4-km resolution. Usually for dust-related studies, high-resolution simulations are conducted only for a few days, particularly during dust storms due to the computational expense (e.g., Prakash et al., 2014; Cremades et al., 2017). In this study, we conduct one present day control simulation using meteorology for the entire year of 2016, and additional control and experiment (with newly exposed playa) simulations for the month of June, 2016. We start the simulations one-week prior, results of which are discarded as spin-ups similar to Fountoukis et al. (2016).

2.2. Observational datasets

Station data are our main source of observations. The stations used in this study are shown in Fig. 2. Wind speed data were obtained from the stations Torres, Salton Park, Bombay Beach, Naval Base, Salton City, Elementary, and Viking. Similarly, PM10 data were obtained from stations Brawley, El Centro, Niland, Westmoreland, and Indio-Jackson.

Fig. 1. Geographical overview of the study area. Red box shows the model domain considered for WRF–Chem simulations in this study.