Incorporation of Planetary Boundary Layer Height Modeling with GIS Techniques to Determine Criteria for Aerosolization and Transport of Infectious Agents in Southwestern United States

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1. Introduction

In the American Southwest, endemic pathogens such as *coccidioides posadasii/coccidioides immitis* (the fungi responsible for Valley Fever) and *coxiella burneti* (the bacteria responsible for Q-Fever) reside in soils, primarily in a zone known as the rhizosphere; a narrow region of intense biological and chemical interaction between plant root systems and the immediate surrounding soil (*Lines-Kelly*, 2005). These infectious diseases are becoming more prevalent, and are a cause for concern (*Doyle 2014; Berg et al 2005; Cromie 2005; CDC – MMWR* 1994). Disease increase may be attributed to a variety of interacting processes. Deserts in the Southwest have been expanding over the past century primarily due to anthropogenic factors (*Reheis*, 1997), and are expected to continue doing so (and perhaps accelerate) under climate change (*Showstack* 2001). Desertification has resulted in widespread transition from native grasses to desert shrubs with concomitant changes in the pattern of vegetation cover and plant rooting systems. Shrubs are distributed more heterogeneously across the landscape with increased and more variable space among plants, resulting in increased soil exposure to erosion via hydrological and atmospheric processes (*Munson et al* 2011; *Puttock et al. 2012*). *Okin et al (2009)* and *Peters (2011)* suggest that changes in the connectivity of the landscape due to desertification impacts a wide variety of processes that feedback to further increase desertification. Hence, it is expected that desertification will continue throughout the region, landscapes will continue to transition to shrubs, soils will become increasingly exposed, and wind and water will increasingly transport those soils downslope to inhabited areas near rivers -- along with the infectious agents contained therein.

2. Methodology

The preliminary focus of this investigation is to conduct an agent-based modeling approach to particulate entrainment; in this case, *coxiella burneti* and *coccidioides posadasii/coccidioides immitis*. An application of numerical modeling techniques will be employed to ascertain the conditions ideal for aerial transport of infectious agents due to interactions between the lower atmosphere and soils patterns associated with different vegetation types. Key to this process are atmospheric conditions in the lower troposphere

(fig 1a & 1b), a regime known as the planetary boundary layer (PBL), where sufficient flux of energy (thermal and mechanical) aide in aerosolization and transport of infectious agents (*Colbeck & Lazaridis* 2014; *Holtslag et al. 2013; Burrows et al.* 2009; *Griffin* 2007). PBL height varies due to diurnal and weather variations, which affect how bio-aerosols migrate within this layer (*Colbeck & Lazaridis* 2014; *Burrows et al* 2009; *Griffin* 2007). Recent advances in atmospheric science have enabled accurate measurement of the height of the PBL at a temporal resolution of 3 hours (*Seidel et al.* 2012). These measurements can be interpolated for any location with ~78 km spatial resolution (*McGrath-Spangler & Denning* 2012; *Seidel et al.* 2012). Hence, preliminary results of this investigation will model pathogen release as a function of PBL height and vegetation type. The model will be spatially-explicit and account for a variety of other environmental factors such as slope and aspect. Once the model is generated, it can be applied to historical conditions and validated through comparison with data on infectious disease prevalence from nearby medical facilities. After validation, the model will be used to forecast future disease prevalence under different scenarios of climate and landscape change. Hence, this investigation will require integrated analysis of climatic, atmospheric, environmental, biologic, and disease processes.

Two locations in New Mexico have been selected for analysis (fig 2), one near Las Cruces in the Chihuahua Desert and the other near Albuquerque on the Colorado Plateau. These sites were chosen because of 1) differences in vegetation (shrub-steppe grasses and desert shrubs, respectively); and 2) proximity to urban areas (approximate population 100,000 and 540,000 respectively).

3. Figures

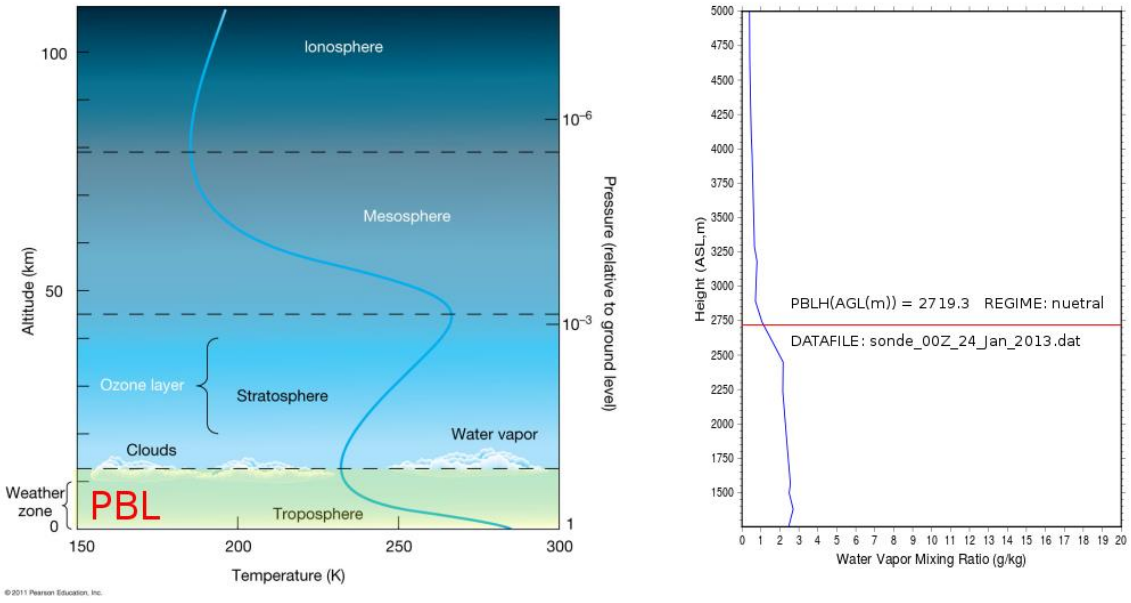

Figure 1: a) Planetary Boundary Layer (PBL) region. b) A sample of a calculated PBL height.

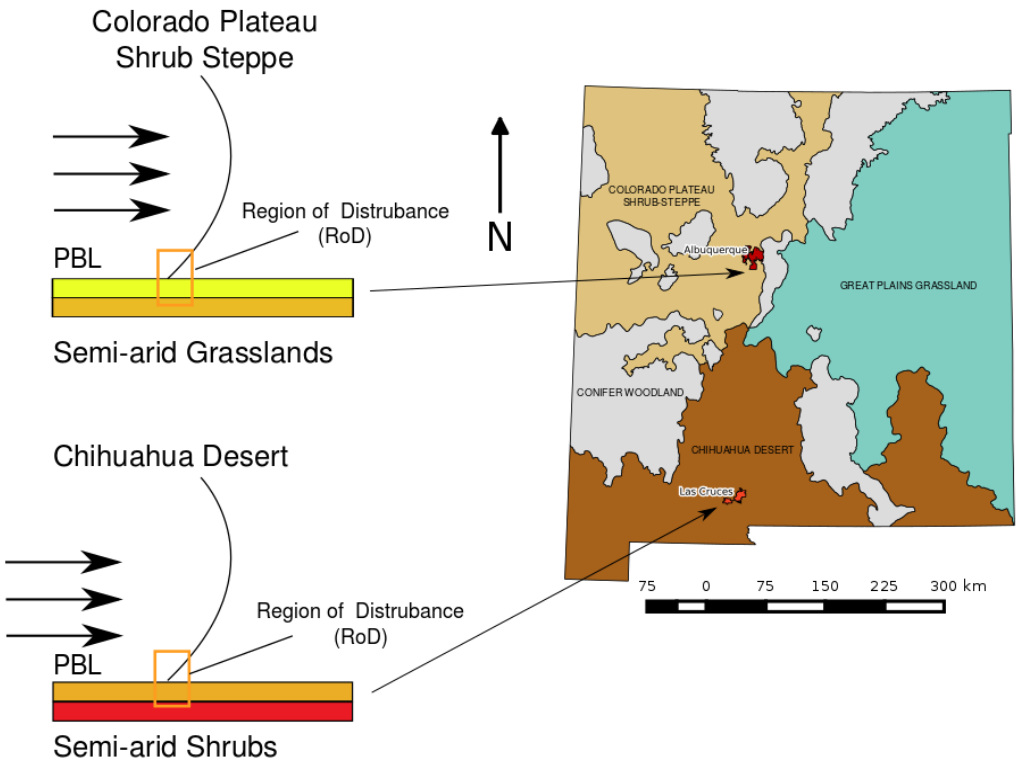

Figure 2: Target regions in New Mexico for investigation.

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