Atmospheric Research 151 (2015) 20–30

Contents lists available at ScienceDirect

Atmospheric Research

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

Invited review article

Fog composition in the Central Valley of California over three decades

P. Herckes [a,*], A.R. Marcotte [a], Y. Wang [a], J.L. Collett Jr. [b]

[a] Department of Chemistry and Biochemistry, Arizona State University, Tempe, AZ, United States
[b] Department of Atmospheric Science, Colorado State University, Fort Collins, CO, United States

ARTICLE INFO

Article history:
Received 12 December 2013
Accepted 30 January 2014
Available online 14 February 2014

Keywords:
Fog
Cloud
San Joaquin Valley
Air pollution
Temporal change

ABSTRACT

Numerous fog studies have been conducted in the Central Valley of California since the 1980s, making it one of the most studied locations in the world in terms of fog chemistry. The present work reviews observational fog studies in the area and discusses overall chemical composition as well as spatial variability and temporal variability. Regionally there is a clear gradient in fog occurrence with less fog and lower density (liquid water content, LWC) fog in the southern part of the Valley (Bakersfield) compared to more northern locations like Fresno or Davis. Chemically, fogs in the southern valley have higher solute loadings and lower pH compared to more northern locations (Davis and Fresno). Overall fog chemistry is dominated in the valley by the ammonia–nitric acid–ammonium nitrate system with sulfate being a rather minor component, especially at more northern locations and in more recent years. Fog pH in recent years is consistently higher than 5, showing an absence of acid in fogs in this region. LWC values appear to have decreased over recent years (less dense fogs). An airport visibility assessment of fog frequency reveals that overall dense fogs (visibility of less than 1/4 mile) have decreased by ~50% over the last 30 years.

Contents

* Corresponding author at: Arizona State University, Department of Chemistry and Biochemistry, Tempe, AZ 85287-1604, United States. Tel.: +1 480 965 4497; fax: +1 480 965 2747.
E-mail address: pierre.herckes@asu.edu (P. Herckes).

http://dx.doi.org/10.1016/j.atmosres.2014.01.025
0169-8095/

1. Introduction

Fog chemistry has been studied since the beginning of the 20th century. Research intensified in the 1980s in conjunction with expanded research on acid precipitation, the role of aqueous phase processes in acidity generation, and the discovery of highly acid fog (Waldman et al., 1982). In the following years, substantial progress was made in understanding acid formation in fog and clouds through laboratory, field and modeling studies. Over time the focus of research efforts shifted from acid generation to the processing of air pollutants and studies of the organic composition of fogs, including current work addressing secondary organic aerosol formation through aqueous phase reactions.

Many field studies have investigated the composition of fogs in the United States (e.g. Collett et al., 2002; Weathers et al., 1988; Raja et al., 2008; Ehrenhauser et al., 2012), in Asia (e.g. Matsumoto et al., 2005; Watanabe et al., 2006; Li et al., 2011) or in Europe (e.g. Fuzzi et al, 1992; Millet et al., 1997; Błaś et al., 2010). In terms of observational fog studies and in particular radiation fogs, two locations were the focus of several observational studies: Italy's Po Valley (e.g. Fuzzi et al., 1992, 1996, 2002) and the Central Valley of California in the United States. Both regions feature large emissions from extensive agricultural activities and other activities associated with a dense population and both have topography and climatological patterns that facilitate fog formation. Radiation fog occurs commonly in both locations during winter.

The Central Valley of California is located between a coastal mountain range to the west and the Sierra Nevada to the east (Fig. 1). It is home to some 6.5 million people. The valley's topography, somewhat resembling a large bathtub,

Fig. 1. Central Valley of California with the locations of various fog studies.