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Fog Research: A Review of Past Achievements and Future Perspectives

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Abstract—The scientific community that includes meteorologists, physical scientists, engineers, medical doctors, biologists, and environmentalists has shown interest in a better understanding of fog for years because of its effects on, directly or indirectly, the daily life of human beings. The total economic losses associated with the impact of the presence of fog on aviation, marine and land transportation can be comparable to those of tornadoes or, in some cases, winter storms and hurricanes. The number of articles including the word "fog" in Journals of American Meteorological Society alone was found to be about 4700, indicating that there is substantial interest in this subject. In spite of this extensive body of work, our ability to accurately forecast/nowcast fog remains limited due to our incomplete understanding of the fog processes over various time and space scales. Fog processes involve droplet microphysics, aerosol chemistry, radiation, turbulence, large/small-scale dynamics, and surface conditions (e.g., partaining to the presence of ice, snow, liquid, plants, and various types of soil). This review paper summarizes past achievements related to the understanding of fog formation, development and decay, and in this respect, the analysis of observations and the development of forecasting models and remote sensing methods are discussed in detail. Finally, future perspectives for fog-related research are highlighted.

Key words: Fog review, fog observations, fog modeling, fog remote sensing, fog forecasting.

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1. Introduction

The effect of fog on human life was recognized in the early ages of mankind but its impact has significantly increased during recent decades due to increasing air, marine, and road traffic. In fact, the financial and human losses related to fog and low visibility became comparable to the losses from other weather events, e.g., tornadoes or, in some situations, even hurricanes. The purpose of this review is to summarize the earlier works on fog and to lay a basis for the articles presented in this special issue and outline perspectives for future fog research.

The earliest works on fog can be traced back to Aristotle's Meteorologica (284–322 B.C.). These were extensively referenced by NEUMANN (1989) in his study of early works on fog and weather. This paragraph is mainly based on his detailed work. In the English translation by H.D.P. Lee (1962, ARISTOTLE), a statement is given on the relationship between fog and good weather. Also, NEUMANN (1989) relates a poem by ARATUS (315–240 B.C.), which was referred to as Prognostication Through Weather Signs, in an English translation by G.R. Mair (ARATUS, 1921). The poem reads " *If a misty cloud be stretched along the base of a high hill, while the upper peaks shine clear, very bright will be the sky. Fair weather, too, shall thou have, when by sea-verge is seen a cloud low (fog) on the ground, never reaching a height, but penned there like a flat reef of rock''*. In this regard, Pliny the Elder (A.D. 23–79, PLINY, 1971), a Roman historian, admiral, scientist and author, states in his work of Natural History "……. *Mist (fog) coming down from the mountains or falling from the sky or settling in the valleys will promise fine weather.''* These works suggested that fog was recognized for use as a fair weather predictor.

The influence of fog was also felt on historical events. LINDGREN and NEUMANN (1980) describe one such event during the Crimean War, when the Russian empire faced the alliance of Britain, France, and Turkey. The allied forces landed in Crimea in September 1854. Intense fog developed early on the morning of the 5th, just when the Russian forces were launching their first major offensive. The allied forces could not realize what was occurring on the other side. It was stated that "…*for the vapors*, *fog*, *and drizzling mist* obscured the ground to such an extent as to render it impossible to see what was going on at a distance of a few yard.'' This suggests that fog was a major player in this historical event.

The formation of fog and its extent at the surface are not easy to predict. The fog formation does not always occur in calm windless conditions. In fact, the formation of fog associated with turbulent windy conditions was studied at the end of 18th century. SCOTT (1896) stated that fogs with strong winds occurred in the British Isles, and sometimes lasted a month. He also mentioned that the strong wind fogs were accompanied by rain which was frequently heavy. SCOTT (1894) showed that fog occurrence was correlated to strong winds (Beaufort scale of 6), and that there was no clear relationship between weather patterns (e.g., cyclonic or anticyclonic) and fog formation. Scott also stated that the total number of fog cases with strong wind was