Tule Fog, Climate Change and Air Pollution

By Chuck Dinerstein, MD, MBA — April 22, 2019

We have all seen, and some of us have experienced, the fog that envelops you creating beautiful landscapes of the Golden Gate Bridge or a valley or forest shrouded in a grayness reducing visibility often to a matter of a few feet. That visibility while beautiful in images can lead to fatalities if you are driving. Fog related motor vehicle accidents average about 31,000 annually, injuring 11,000 and killing 500 — that mortality is greater than deaths attributable to heat, floods, lightning and tornadoes combined. [1]

The Tule Fog, a very dense, visibility limiting, characteristic of California’s Central Valley has been in decline for several decades. Scientists now believe that a reduction in air pollution, rather than climate change per se is responsible. How does this come to be the case? To understand the science and the new findings we have to begin with fog and how it is formed.

What wonders are hidden within Fog?

For all of us who have imagined walking within the clouds as our plane follows the final approach, fog, which is nothing more than a very low lying cloud provides the opportunity. Like it’s higher flying cousins, fog is condensed water vapor. From a scientific point of view, the visible condensation of water from our atmosphere requires a cool, unmoving air mass trapped underneath a warm air mass.

For Tule fog, the winter months, November through March are prime for nighttime radiational cooling and for higher lying warm air to push down trapping that cold air in the Central Valley, which is surrounded by mountains obstructing airflow. The amount of water vapor held by the air, humidity or in our case, the dew point [2], is a function of temperature, with higher temperature...
holding onto more water as vapor. When the air suddenly cools, the atmosphere can no longer hold onto the vapor and it condenses into liquid, although it is a very fine mist that we call fog. The condensation or precipitation of liquid water is accelerated by the presence of air-borne solid particles that provide a nucleus for condensation to start.

With sunrise, the air can begin to warm and the process reverses itself, more liquid water is returned to the atmosphere as vapor; the fog burns off.

**California’s Central Valley**

The Central valley is one of the most productive agricultural regions in the US. It lies in the center of the state stretching predominantly in a north-south direction for about 450 miles, bounded by the Sierra Nevada and California’s Coastal Ranges. It produces more than 230 crops and “half of the fruits, vegetables, and nuts grown in the United States.”

**What the scientists uncovered**

That climate is impacted by air pollution has been known at least since the London Smog of 1952. For the period from 1930 to 1970 dense fog days nearly doubled, increasing by 85%. Since 1980 those fog days have decreased by a similar amount (76%), and the fog formed later in the evening and dissipated more quickly. Additionally, there was a marked gradient in fog with far less in the northern parts of the valley and less of a decrease in the south. As the scientists currently report, it is the diminishing presence of air pollution in the Central Valley that seems to be the cause of diminishing fog.

The Central valley is among the most air polluted in the country. More specifically, the presence of winter’s climate and fertilizer allow for the formation of ammonium nitrate a PM2.5 particulate; and ammonium nitrate is unique in its ability to create conditions favoring fog at lower dewpoints and with smaller sized water droplets, increasing fog’s longevity and cloudiness. Because of the extensive use of fertilizer in the Central Valley, the ammonium component is abundant and the formation of ammonium nitrate is most sensitive to the concentrations of NO\textsubscript{2}, an air pollutant. [3]

The researchers used several datasets to capture the incidence of fog, as fog days and hours, as well as temperature, dewpoint, wind speed and atmospheric levels of NO\textsubscript{x}— all the ingredients in fog’s recipe.

- Fog needs cold favoring the northern part of the Central Valley, but the temperature has been warming throughout the valley, so that alone could not explain the diminished amount of fog, especially in the north.
- Precipitation has increased in the Central Valley, again more in the north than south. Precipitation provides the necessary water but the winds associated with storms often create turbulence that impedes fog’s formation.
- Winds across the entire valley have not favored fog formation for some time and again do not explain the north-south fog gradient.
- Dewpoint depression (DPD) must be close to zero for fog to form. While the north has the highest DPD, reducing fog, areas with the lowest DPD did not show the greatest amount of fog days.
For the optimum conditions for fog formation, fog resulted more than 55% of the time in the 1980s; while those identical climatic conditions now result in fog about 35% of the time. The only factor that mirrors the change in fog formation is the levels of NO\textsubscript{x}.

Given the data, the scientists concluded that the diminishing presence of ammonium nitrate, resulted in less nuclei to initiate and sustain the formation of fog. And the lower amounts of ammonium nitrate “fell in concert with NO\textsubscript{x}” both temporally and geographically across the valley, mirroring that north-south gradient. Put in other terms, as meteorological conditions come closer to forming fog, fog formation becomes more sensitive to the presence of the particulate matter that initiates condensation, in this case ammonium nitrate. With less ammonium nitrate in the atmosphere because of cleaner air, it’s “catalytic” effect diminished.

Just as the human activities, urbanization, fuel usage, and home heating inefficiencies resulted in more air pollution; human responses like catalytic concerters and power plant stack controls have resulted in declines. In both instances, our actions impacted the climate, often in unintended ways. It is easy to point at how air pollution increased Tule fog and resulted in more traffic accidents and fatalities. And it is worthwhile to show how our efforts to reduce pollution has resulted in less of that dangerous fog.

**An Unintended Consequence?**

But the fog plays another role in the Central Valley. It provides a degree of winter cold, and that can be important to an agricultural area. Fruit and nut trees are often dormant in the winter and require a certain amount of chilling, “chill hours,” to induce flowering and “set fruit.” Without the cold, in certain instances, there may be a poor crop or no harvest at all. For example, a 11% reduction in chilling time for a species of peaches reduced yield by 50%. So while we should cheer that our air is becoming cleaner, we must wait to see whether the climatic conditions that clean air provides not interfere with supplying us with food.

[1] **Fog**: Deadlier Driving than you think.

[2] Dewpoint is a specific measure of humidity indicating the point at which the humidity and temperature will allow the vapor to liquid condensation to begin.

[3] Chemically, \( \text{HNO}_3 + \text{NH}_3 \rightarrow \text{NH}_4\text{NO}_3 \). \( \text{NO}_2 \) in the form of \( \text{HNO}_3 \) is the rate limiting agent.

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