Testimony
Background Check: Achievability of new Ozone Standards

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As an atmospheric scientist with 30 years experience in air quality research, I am happy to provide testimony on background ozone. My scientific judgment can be summarized as follows:

- Ozone at concentrations between 60 and 70 ppb is harmful to the environment and to human health, causing sickness and death.

- Natural processes such as forest fires and downward transport of ozone from the upper atmosphere are sources of ozone in remote regions and even high altitude sites such as the intermountain west.

- These natural or uncontrollable processes are rarely important for the vast majority of areas in the U.S. designated nonattainment or where air pollution is known to be a problem.

- When high concentrations of ozone from natural processes, or causes beyond the control of States are detected, they have been identified and designated Exceptional Events by the EPA; these do not count against attainment status.

- High ozone from natural causes in the intermountain west can be identified from unique chemical signatures; these episodes can and should be designated "Exceptional Events."

- The NAAQS for ozone should be set to no more than 60-70 ppb as recommended by the USEPA in 2006 based on compelling scientific evidence; this standard is achievable with existing technology and necessary to protect welfare and human health.

Laboratory and field studies show clear, consistent evidence of a causal relationship between short-term ozone exposure and harmful respiratory health effects such as cough, wheeze, and shortness of breath. The USEPA assembles experts from around the country to review and summarize the scientific data on Criteria Pollutants – the reports were called Criteria Documents (CD's) and are now referred to as Integrated Science Assessments (ISA's). Evidence developed since the 2006 Criteria Document on which I was a coauthor now indicate that ozone can also contribute to death from respiratory causes. The very young, old, and asthmatics are especially sensitive. Children who spend more time outside and have breathing rates higher than most adults are at increased risk. Adverse effects have been measured at concentrations as low as 40 ppb, but evidence is compelling that ozone in concentrations above 60-70 ppb causes substantial morbidity and mortality – that is sickness and death. The best estimates of mortality from air pollution in America are about 30,000 people per year – about the same as from traffic

accidents. The evidence is strong that ozone also produces adverse cardiovascular, reproductive, and central nervous system effects. The 2006 Criteria Document [*EPA*, 2006b] includes summaries of hundreds of studies of the impact of ozone on human health compiled and vetted by outstanding, highly qualified health scientists. Their conclusion that the NAAQS should be set to between 60-70 ppb is founded on compelling evidence and years of careful study. I supported this recommendation and confirm that support today.

In addition, ozone is a phytotoxin, harmful to plants, both wild and agricultural. Valuable crops and produce are damaged by even modest concentrations of ozone, and the economic losses from this damage are substantial. Reducing ozone protects America's farms and forests.

Reductions in emissions of ozone precursors (the pollutants that combine with UV radiation to make ozone in the atmosphere) have been highly successful – even more effective than had been predicted by models [*Bloomer*, 2008; *Bloomer et al.*, 2010; *Bloomer et al.*, 2009; *EPA*, 2006a; b; 2013; *Gilliland et al.*, 2008; *Marufu et al.*, 2004; *Oltmans et al.*, 2013; *Rieder et al.*, 2013]. Past efforts have focused mainly on reducing emissions from power plants and automobiles. Many major sources such as other internal combustion engines, industrial boilers and small power plants, and off-road sources remain uncontrolled or under-controlled. There is a clear path for further reductions in surface ozone.

Natural ozone from high altitudes (the stratosphere[*]) does indeed enter the troposphere (the lowest ~10 miles of the atmosphere), and can be definitively identified from the composition of these air parcels; I have personally flown on research aircraft penetrating these high altitude events, called tropopause folds, [*Cooper et al.*, 1999]. They are well characterized by low humidity and low concentrations of CO, SO_2, hydrocarbons, and other manmade pollutants along with high concentrations of ozone. All these events were seen at high elevation. Natural ozone is an important source for the remote atmosphere, but the bulk of the ozone in the part of the atmosphere where Americans live is manmade – in urban areas the origin of ozone is overwhelmingly anthropogenic (manmade) [*Lamarque et al.*, 2013; *Stevenson et al.*, 2013]. Likewise air pollution from Asia can reach the western United States, and I have been involved in direct measurements of the chemistry and transport of pollution from China [*Dickerson et al.*, 2007; *He et al.*, 2012; *C Li et al.*, 2010; *Z Q Li et al.*, 2007]. Long-range transport of dust and pollutants from China and India has major impacts on global atmospheric composition and probably climate, but they rarely if ever contribute substantially to pollution events for non-attainment areas. State of the art computer simulations indicate that anthropogenic sources from outside North America account for 5-7 ppb background increase in the West in spring (this includes methane's effects), but less in other seasons [*Zhang et al*., 2011]. Other models seem to agree on that amount, for example a the maximum surface ozone attributable to Asian pollution in the western U.S. of 3.4 ppb in

[*] Note ozone at high altitudes in the stratosphere, the good ozone, protects us from dangerous UV radiation; ozone in the troposphere, the bad ozone, is toxic.

the spring and 1.4 ppb in the summer [*Brown-Steiner and Hess*, 2011]. See also [*Huang et al.*, 2013; *Lei et al.*, 2013]. Less Asian ozone makes it to the eastern U.S.

Having measured the chemistry and meteorology of pollution events in the eastern U.S. for more than 20 years, I can testify that we have never seen a surface ozone episode with a major impact from high altitude, natural ozone. If we were to discover one, my group would find it an exciting, surprising event and write a scientific paper on it immediately.

Occurrences of high concentrations of ozone at high altitude background sites in the western U.S. are worthy of further research and cause for concern. The people of Colorado, Utah, Wyoming and other intermountain states are just as deserving of clean air as the rest of America. The high concentrations of ozone are hazardous to human health – there may be occasions where there is simply nothing the local authorities can do about it.

Computer simulations (numerical models) are valuable in determining the impact of natural ozone and pollution from outside the U.S. These simulations indicate that emissions from vehicles and industry dominate the production of ozone in metropolitan areas. Early models had difficulty simulating these events, but more recent work handles natural ozone better [*Lin et al.*, 2012; *Zhang et al.*, 2011]. A different model, CAMx, produced background ozone 10 ppb higher in the west and 5 ppb higher in the East [*Emery et al.*, 2012]. These and other numerical simulations however continue to indicate a minor a role for natural ozone on polluted days in heavily populated areas. Numerical models consistently indicate less than 35 ppb for most of the eastern U.S. [*A Fiore et al.*, 2003; *Fiore et al.*, 2002; *Wang et al.*, 2009; *Wu et al.*, 2008]. More recently developed models such as AM3 are not 'more advanced' than the model used previously (GEOS-Chem) in all important respects. AM3 better represents certain meteorological interactions (and chemistry-climate interactions), but in many aspects involving tropospheric chemistry and other processes influencing ozone, GEOS-Chem is clearly pioneering. Finding high levels of ozone at high altitude does not in any way indicate a high background for the eastern U.S. and California during smog events. The amounts are too small, in the wrong place and at the wrong time. The same is true for ozone from lightning. The amounts are small compared to anthropogenic (manmade) emissions, the emissions are at high altitudes, and occur during thunderstorms when ozone levels at the surface plummet. In other words natural ozone is too little, and at the wrong place and wrong time to have a significant impact on smog events in the eastern U.S.

Concern has been expressed that remote, high altitude sites could be declared in non-attainment based on high concentrations of ozone that are beyond the control of the State. The appropriate response to ozone episodes that can be proven to be natural, such as from ozone from high altitudes or forest fires, or from distant source such as Asia, is to declare them "Exceptional Events". As defined by the EPA, "Exceptional Events are unusual or naturally occurring events that can affect air quality but are not reasonably controllable using techniques that tribal, state or local air agencies may implement in order to attain and maintain the National Ambient Air Quality Standards."
http://www.epa.gov/ttn/analysis/exevents.htm This system works. Massive forest fires

in Quebec generated a smoke pall (containing PM and ozone) that covered much of the eastern U.S. in July 2002, but scientific evidence that this was a natural phenomenon made it possible for Maryland to have this episode designated an Exceptional Event and it did not count against the State in terms of attainment of the NAAQS. We wrote several scientific papers on this episode [*Colarco et al.*, 2004; *Taubman et al.*, 2004; *Vant-Hull et al.*, 2005]. My colleagues, graduate students, and I used both aircraft measurements and satellite observations (freely available from NASA and NOAA) in these studies. A recent publication on high surface ozone events presented data (Table 1) for this specific purpose [*Lin et al.*, 2012]. California and Kansas have successfully petitioned to have ozone exceedances declared "Exceptional Events".

Measuring ozone and weather variables alone may be insufficient or even misleading about the origin of unhealthy air. High concentrations of ozone (>70 ppb) were consistently observed at Bermuda, and attributed on the basis of meteorological analyses to natural causes, a surprising result given that Bermuda lies just ~600 miles off the East Coast [*Oltmans and Levy II*, 1992]. A more thorough examination of these ozone episodes, however, revealed high concentrations of carbon monoxide (CO), hydrocarbons, oxides, of nitrogen (NOx), and other indicators of industrial pollution and car exhaust [*Dickerson et al.*, 1995; *Milne et al.*, 2000; *Prados et al.*, 1999] proving that these episodes were indeed manmade. Computer simulations (models) reached similar conclusions [*A M Fiore et al.*, 2003; *Q B Li et al.*, 2002].

Forest fires do not generally produce high concentrations of ozone unless mixed with urban emissions [*Singh et al.*, 2012; *Singh et al.*, 2010]. Further research is required to determine the relative contributions of natural and man made emissions to ozone related to forest fires.

Proving that high ozone concentrations observed at high altitude sites in the western U.S. is the result of clean, upper atmospheric (stratospheric) air is straightforward and practical. Reliable carbon monoxide and sulfur dioxide (SO_2) monitors are commercially available, and have an excellent track record in compliance monitoring. Pollution ozone is essentially always associated with vehicle exhaust containing CO or with coal combustion plumes containing SO_2. If the ozone increases and neither CO nor SO_2 increase with it then the ozone is from a natural source. These episodes can and should be declared Exceptional Events.

Obtaining the scientific evidence to have an ozone episode designated "Exceptional Events" requires technical effort. NASA has assembled and supports the Air Quality Applied Science Team (AQAST) to serve the needs of U.S. air quality management through the use of Earth Science satellite data, observations from the surface and aircraft as well as models. http://acmg.seas.harvard.edu/aqast/index.html One of the AQAST tasks is to provide data on stratospheric intrusions (natural ozone) and forest fires. The NASA AQAST is already working with western States on identifying exceptional ozone events and would be happy to expand those efforts.

The state of the science is sufficient to take action. All scientific findings have associated uncertainty. Scientists revel in finding and measuring this uncertainty; it leads to ever increasing understanding and accuracy. The level of confidence related to the NAAQS for ozone, however, is high. The evidence is compelling. A multitude of measurements confirm the fundamental theory of ozone production from pollution. Stratospheric intrusions and long-range transport are scientifically fascinating and worthy of further research, but the background ozone from such processes is small compared to manmade ozone during smog events in heavily populated areas. To protect the natural environment, farms and forests, but most of all human health, an ozone standard of no more than 60-70 ppb is urgently needed.

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