ATMOSPHERE

Challenges of a lowered U.S. ozone standard

Source attribution science can help areas of the U.S. west

By **Owen R. Cooper,**[1,2]* **Andrew O. Langford,**[2] **David D. Parrish,**[1,2] **David W. Fahey**[2]

At Earth's surface, ozone is an air pollutant that causes respiratory health effects in humans and impairs plant growth and productivity (*1*). The Clean Air Act (CAA) of 1970 mandates that the U.S. Environmental Protection Agency (EPA) assess the ozone standard every 5 years and revise when necessary to protect human health. With a decision expected in October 2015 as to whether the standard will be toughened, we discuss limitations of ozone and precursor observations that hinder the ability of state and local air pollution–control agencies to accurately attribute sources of ozone within their jurisdictions. Attaining a lower standard may be particularly challenging in high elevations of the western United States, which are more likely to be affected by ozone that has been transported long distances or that originated in the stratosphere.

POLICY

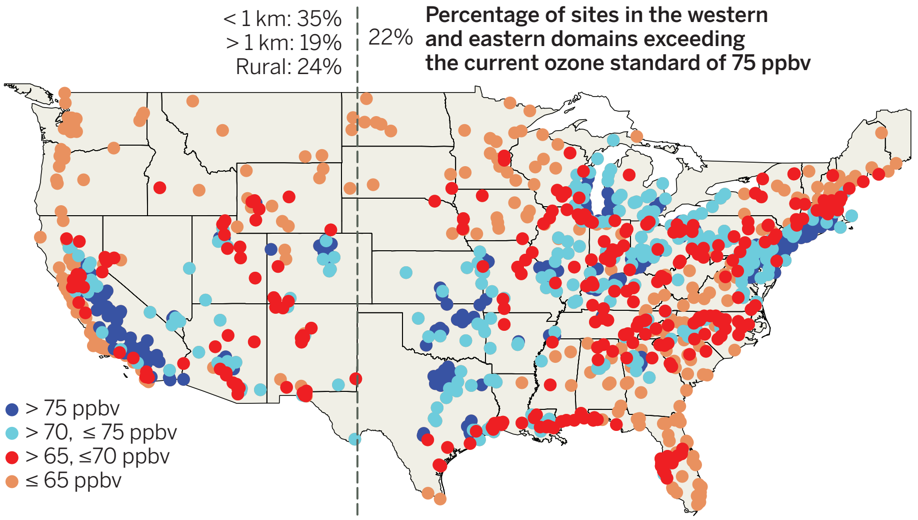
Understanding the origins of surface ozone is complicated by its multitude of sources. Ozone is transported to the surface from the natural reservoir in the stratosphere or produced from precursor gases [nitrogen oxides (NO_x) and volatile organic compounds] that react in the presence of sunlight. Ozone precursors have natural sources—such as vegetation, wildfires, and lightning—and are also emitted by human activity—such as combustion of fossil fuels and human-caused biomass burning.

The current primary (health-based) EPA standard is 75 parts per billion by volume (ppbv), with 227 U.S. counties, home to 123 million people, classified as not having attained the standard (www.epa.gov/airquality/greenbook/index.html). In November 2014, EPA proposed a revised primary ozone standard in the range of 65 to 70 ppbv in order to improve public health protection (*2*). The most recent ozone "design values" were used to determine whether ozone observations comply with the standard (which is based on the 3-year average of the fourth-highest daily maximum 8-hour ozone average in each year) at all EPA-approved ozone-monitoring sites (see the chart). The highest values are in large urban areas. Recent data from 2011 to 2013 reveal that 358 and 558 counties have design values that would exceed a revised ozone standard of 70 and 65 ppbv, respectively (www.epa.gov/groundlevelozone/maps.html). The good news is that ozone design values are declining because of ongoing reductions in precursor emissions resulting from regulations such as the "NO_x SIP Call," a state implementation plan that took effect across 22 eastern states in 2003, and the nationwide Tier 2 Vehicle and Gasoline Sulfur Program that began in 2004. EPA expects these emissions trends to continue through 2025 owing to already promulgated regulations (*3*).

Although ozone design values are generally declining across the United States, the trends are weakest at rural high-elevation sites in the western United States (>1.5 km above sea level) (*4*). One potential reason is greater exposure to enhanced "baseline" ozone that flows across the North Pacific Ocean or is transported downward from the lower stratosphere (*5*–*9*). Baseline ozone is transported from all upwind sources (natural and anthropogenic) before modification by recent, localized emissions; it includes aged ozone, produced many days earlier from U.S. emissions, that is returned to the United States after circling the globe. Baseline ozone can be directly observed by surface or airborne instrumentation along the West Coast or U.S. political borders and above inland regions of the western United States in air masses not influenced by recent U.S. emissions. Note that baseline ozone plumes produced from routine anthropogenic emissions outside of the United States cannot be classified as exceptional events, which are unusual exceedances of the ozone standard that EPA removes from consideration when classifying an area as having nonattainment.

Observed springtime baseline ozone 3 to 8 km above western North America has increased significantly since the 1980s and 1990s, and the trend is strongest in air masses that are transported directly from South and East Asia (*4*). High-elevation regions of the western United States are more strongly influenced by baseline ozone than locations at lower elevations, especially in springtime (*7*–*9*). However, model studies

EPA-approved ozone monitoring sites



Ozone design values at all EPA ozone monitors operating during 2011–2013. The vertical dashed line separates the high-elevation regions (>1.5 km) of the west from the east. Western sites are divided into those above and below 1 km above sea level, with a separate overlapping category of rural sites. [Ozone values source: www.epa.gov/airtrends/values.html]

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[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309, USA. [2]Chemical Sciences Division, NOAA Earth System Research Laboratory, Boulder, CO 80305, USA.
*Corresponding author. E-mail: owen.r.cooper@noaa.gov

(*10–12*) and ozone observations above the California coast (*9*) and rural Nevada (*6*) also indicate substantial baseline ozone at low-elevation rural and urban (<1.5 km) sites in the western United States.

EPA is aware of ozone variations across the western United States and has conducted targeted research for the latest ozone standard review (*1*, *3*) by focusing on the estimation of North American background ozone levels (*10*, *11*). This is ozone that would exist in the absence of any anthropogenic ozone precursor emissions from North America. Although background ozone is a large component of baseline ozone, it differs from baseline ozone because it cannot be measured by instruments but must be calculated by global-scale atmospheric chemistry–transport models. Background ozone indicates the proportion of observed North American ozone that is beyond the control of domestic air pollution–control measures; these estimates also inform U.S. air-quality managers how much domestic emissions must be reduced in order to attain the ozone standard. Although the CAA requires EPA to set the ozone standard at levels requisite to protect public health and welfare without regard to the source of the pollutant, EPA does view background ozone as an important concept to understand and quantify in developing implementation policies. Using two separate global-to-regional air-quality modeling approaches, EPA estimated that background ozone makes substantial contributions to surface ozone in the western United States (*1*, *3*). Seasonal (April to October) mean background levels ranged from 40 to 45 ppbv across much of Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming, with some individual days approaching the range of the proposed standard (i.e., 65 to 70 ppbv).

EPA has stated that "[e]xisting and upcoming EPA regulations and guidance will assist states in ensuring background ozone does not create unnecessary control obligations" (*13*). However, these mechanisms require states and EPA to be able to quantify the overall contribution and sources of background ozone. The role of scientists is to inform the decision-making by conducting research to accurately quantify background ozone. The challenges are model accuracy and limited observations of baseline ozone, which require further development and enhancement in order to improve the quantification of background ozone. A comparison of two global models shows that they differ in their estimates of monthly mean background ozone by as much as 10 ppbv and produce different seasonal cycles (*12*). Global models also have deficiencies in reproducing long-term observed ozone trends at northern mid-latitudes, which indicates the need for model improvements related to production or transport of ozone (*14*). Although the U.S. surface-ozone observation network is extensive, the observations for evaluating model estimates of surface and free troposphere baseline ozone along the 1800-km U.S. West Coast are extremely limited. There are only two measurement sites representative of marine boundary layer ozone (Trinidad Head, CA, and Cheeka Peak, WA), and two coastal mountain sites representative of lower tropospheric baseline ozone [Mt. Bachelor, OR (*15*), and Chews Ridge, CA]. The only routine ozone profiles from sea level to the stratosphere on the West Coast are made just once per week at Trinidad Head.

> ***"Background ozone… estimates also inform U.S. air-quality managers how much domestic emissions must be reduced…"***

From both scientific and regulatory points of view, a lower ozone standard will motivate air quality–control planners to seek more accurate and precise attribution of observed ozone to local, upwind, and stratospheric sources of ozone to determine how much domestic emissions must be reduced in order to attain that standard. A lower ozone standard will also increase the probability that the standard will be exceeded in springtime, which would require the attribution of ozone episodes beyond the typical summertime period of concern. Accurate quantification of background ozone under this new paradigm would require enhanced baseline ozone observations at a spatial density and temporal frequency adequate for evaluating and improving the models. Once the models can replicate baseline ozone, greater confidence can be placed in their estimates of background and locally produced ozone.

Additional observations include routine vertical ozone profiles at multiple coastal and inland sites using balloon-borne ozonesondes, ground-based ozone lidars, or, possibly, commercial aircraft. Related options include augmenting the U.S. Tropospheric Ozone Lidar Network (TOLNet), the U.S. National Oceanic and Atmospheric Administration (NOAA) Global Greenhouse Gas Reference Network aircraft program, or the European In-Service Aircraft for a Global Observing System (IAGOS). New ozone and precursor monitoring sites at inland rural locations (especially high elevation) would be useful for gauging the descent of baseline ozone from the free troposphere into the boundary layer.

These additional observations would improve detection of interannual variability (*12*) and long-term trends in baseline ozone. The observations would be used to improve the coarse-scale global models needed for the routine estimation of background ozone and precursors that are subsequently downscaled and included in the best regional air-quality models covering the United States. Along these lines, the United Nations Task Force on Hemispheric Transport of Air Pollution is evaluating multiple global- and regional-scale model estimates of baseline and background ozone across the western United States—but only for a very limited time period when sufficient observations are available. If a revised ozone standard is adopted, air quality–control programs will have a greater need to precisely and accurately attribute ozone sources on a continuous basis, and systematic and long-term efforts of scientists will be required to help identify and fill gaps in observations and modeling capabilities in coming years. ■

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