Spatial and temporal patterns of ozone in the high elevation ecosystems of the Colorado Rocky Mountains

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Background

- Ozone is a strong oxidant in the troposphere that is regulated by the US EPA to protect human health and welfare. High ozone is known to cause respiratory problems in humans, but can also damage ecosystems.
- The majority of ozone at the surface today is related to anthropogenic activities. Ozone forms in the troposphere from the interaction of nitrogen oxides and volatile organic compounds in the presence of sunlight. Because these gases largely come from transportation and industrial activity, ozone has typically been thought of as an urban problem. However, there is growing recognition that ozone is a problem in rural areas, especially in the western US. One region with surprisingly high ozone concentrations is the high elevation ecosystems in Colorado.
- The goals of this study are to use existing ozone monitoring data to examine spatial and temporal trends in ozone in the high elevation ecosystems of the Colorado Rocky Mountains and to investigate how ozone may be affecting the species composition and productivity in these ecosystems.

Why is ozone potentially a problem in high elevation ecosystems in Colorado

While ozone concentrations are regulated, ozone fluxes cause damage to plants. There is a temporal offset between the two, with the maximum flux typically occurring several hours earlier than the maximum concentration (Fares et al. 2013). In addition, the total flux is not all damaging to plants: some of the flux is associated with chemical breakdown in the canopy as well as non-plant surfaces such as soils (Kanemasu and Goldstein 2003, below). While fluxes have been measured at one site in the subalpine forest, there are no data for the tundra in Colorado.

What we know about ozone in high elevation ecosystems in Colorado

There are relatively few long-term records at high elevation sites in Colorado (below), but there are not clear trends across all sites. The two sites with the longest record (Longo Peak and Gothic) show opposite trends over the last 25 years (right). For the Front Range sites (i.e. excluding the Gothic site), the median annual ozone generally increased in 2010. In 2010 all of the Front Range sites were near or above the current EPA standard for ozone (75 ppbv for the 8th highest 8 hour average, below right). Using both the EPA standard and the highest elevation site (Niwot tundra) is the most of compliance. Exposure-based standards (SUM6 and W126) show the same pattern. Unlike the lower elevation sites, the Niwot Ridge sites have a significant fraction of the high concentration periods at night.

How does ozone affect vegetation

The effects of ozone on plants can be observed at multiple scales (Ainsworth et al. 2012). The damage at the cellular level occurs when ozone enters the plant through stomata. These effects translate into decreased plant function (e.g. photosynthesis, tissue damage) at the individual level. The damage can be visible to the naked eye, such as the cut leaf coneflower leaf above (Kohli et al. 2012), but damage can lead to effects at the community level: decreased biomass and net primary production, and changes to community composition.

During a one year study in 2007, the ozone mixing ratios generally increased along an 40 km transect from Boulder (BO) at 1608 m to the alpine tundra (TL) at 5238 m on Niwot Ridge (Boshoff et al. 2010). In the summer and the spring there is large diurnal variability in the mixing ratios, but the daily range is lower at the higher elevation sites. While all sites show a maximum mixing ratio in late afternoon, the ozone mixing ratios remain high throughout the entire day at the highest elevation sites.

The Niwot Ridge sites are part of the NSF-funded Long Term Ecological Research program. While to many ways this site is less affected by human activity than other LTERR sites, it likely has the highest ozone concentrations of any LTERR site. It is also likely representative of the high ozone concentrations throughout the tundra in Colorado.

Summary

- Ozone continues to be above the EPA standard in rural areas of the western US associated with local, regional and long-distance pollution. Mixing ratios and exposure-based indices were highest at the alpine tundra site during the spring. Mixing ratios were relatively high at night and in winter, but this is less likely to cause plant damage.
- There is no ozone flux data for alpine sites in Colorado and little information on damage currently occurring in these high elevation ecosystems. It is possible that these plants are more adapted to the higher ozone that naturally occurred at high elevation, but significant damage may also be caused by anthropogenic pollution.

Acknowledgments

The sensitivity of plants to ozone is also dependent on the environmental conditions. During drier conditions, plants may be less sensitive to ozone because they close their stomates to prevent water loss (Paton et al. 2002).

References


