The case for continual ozone research

NASA's Earth Science Division has advanced our understanding of atmospheric ozone and revealed that there is still lots to discover about this complicated compound.

Thirty years of the Montreal Protocol

This September marks the 30th anniversary of the Montreal Protocol, the international agreement largely attributed with solving one of society's greatest environmental challenges: the thinning of the stratospheric ozone layer.

The Montreal Protocol put into place key restrictions on chemical compounds known to damage the ozone layer. For thirty years, signatories to the agreement have avoided, regulated, and created substitutes for these harmful compounds; and now, we're beginning to see the results.

Three satellites, dozens of airborne campaigns, and countless balloon launches later, we're finally beginning to see the ozone hole recover. Scientific studies using NASA data have concluded that from 2000 to 2015, the average extent of the September Antarctic ozone hole shrank by about 4.5 million square kilometers[1]—this during a season when the ozone hole typically increases in size. In addition, a 2014 assessment by the World Meteorological Organization found that the ozone hole had even begun to recover at high elevations in mid- and low-latitudes.[2]

Although scientists believe the Montreal Protocol is to thank for much of this success, it's only a piece of the larger puzzle. In fact, the observed rate of ozone recovery has been much faster than originally anticipated with the Montreal Protocol alone, leading many in the scientific community to conclude that the real reason is much more complicated and that there's still more to learn.

Settled science? What we still don't know about ozone

Comment [AS1]: I'm going to refine these lists.

Here's what else we know about ozone:

- We know that volatile organic compounds from man-made (e.g. power plants and cars) and naturally occurring (large forested areas) sources create ozone near the Earth's surface.
- We know that chlorine- based compounds are especially harmful to stratospheric ozone.

Here's what we don't know about ozone:

- We don't know how ozone transported throughout the atmosphere. Does ozone from stratosphere—where want it—ever sink down into the troposphere—where we don't want it?
- We don't know how to dynamic meteorological events, such as severe storms, affect the distribution of ozone in the atmosphere.
- We don't know how will changes in Earth's climate will affect the distribution of ozone vertically in the atmosphere and around the world.
- We don't know how chemical compounds of the future might affect the ozone layer.
- We don't know whether countries will continue to adhere to the tenets of the Montreal Protocol in the future.

[1] http://www.sciencenews.org/article/despite-volcanic-setback-antarctic-ozone-hole-healing
[2] Need citation.

The need for NASA Earth Science

Ozone concentrations are a global problem—both in the stratosphere and the troposphere. Chlorofluorocarbons and other chemical compounds from around the world contributed to the depletion of the stratospheric ozone layer; and tropospheric ozone created at a factory in one location can be easily spread into another, regardless of country borders or even oceans. Therefore, NASA's global view of ozone concentrations is critical to advance our understanding this complicated compound.

Research conducted across NASA's Earth Science Division (ESD) has helped advance what we know about ozone, its chemical precursors, and how humans influence ozone depletion and creation.

- What we're learning from current satellite missions and instruments
  - Aura (OMI, MLS, TES)
  - Aqua (AIRS)
  - S-NPP (OMPS)
  - ISS (SAGE III)
- What we're learning from recent airborne campaigns
  - DISCOVR-AQ
  - KORUS-AQ
  - ATom
  - LMOS 2017
  - ATTREX
- What we've learned from ozonesondes
  - NDACC
  - AGAGE
  - SHADOZ
  - AERONET
- What we've learned from ground retrieval systems
- What we've learned from modeling

Comment [AS2]: These will be bulleted paragraphs highlighting science results from across these different instruments and campaigns.

The importance of comprehensive, long-term datasets

We expect the ozone hole will get better, but its recovery will not happen overnight. It's critical that we continue to monitor the progress of the ozone hole for all of our health and safety. The path to recovery for the ozone hole will be very long, and we must make sure that the actions we're taking have the intended effect. It's important that we continue to monitor any slight variations that may occur in the ozone hole to ensure its continued recovery, and monitor for any other smaller disturbances that could signal larger things to come.

Investing in ozone research means investing in the public health and safety of the entire country. Increased risk of death from respiratory illnesses. Overexposure to ozone has led to X percent more deaths in 20XX, and also the loss of more than X percent of crops across the U.S. and the world.

Comment [AS3]: Will include specific stats.

New and emerging chemicals could delay the recovery of the ozone layer (ex: dichloromethane could delay ozone recovery by 30 years). Are people are adhering to the Montreal Protocol.

Important to maintain integrity of the data and we're still not sure how the ozone hole will react. We expect it will get better, but this is something that takes time that we must continue to monitor for our health and safety.

Pop-out box: Measuring ozone from the ground up (and space down)

We are really good at using satellites to see ozone in the stratosphere. We are not good at using satellites to see ozone lower down in the atmosphere.

Size comparison. Cost comparison. What other chemical compounds they see. What we've learned. Drawn to scale?