



2019 Governor's Awards for High-Impact Research

PROJECT NOMINATION FORM

SUBMISSION DEADLINE: 5:00 pm on Monday, October 14, 2019

Consideration of these Awards is open to research laboratories and institutions in Colorado that receive 51 % or more of their funding from federal sources.

Select one of the following four categories for your nomination. *(Each organization can submit up to two nominations)*

- Pathfinding Partnerships:** For those projects whose results leveraged creative, even unique collaborations among disparate and/or multiple partnering organizations
- Remarkable Revelations:** For projects that revealed profound new understandings of foundational dynamics and/or theories within a given field
- Manifestation Mastery:** For projects that resulted in widespread public awareness, utilization and impact on a given challenge or issue
- Discovery of the Year:** For projects that demonstrate a compelling range of scientific discovery, public impacts and uniquely creative processes of research that include (but not limited to) characteristics of the first three category themes above

Please note: if you submit a nomination for one of the first three categories, the project will be judged within ONLY that category against any other nominations for that same category.

If you submit for Discovery of the Year, your nomination will be vetted against all nominations. We are leaving the option open for our Selection Committee to rank any nomination "Discovery of the Year".

NAME OF LABORATORY/INSTITUTE(s): NOAA Earth System Research Laboratory

PERSON SUBMITTING THIS NOMINATION: James Butler

Title: Director of the Global Monitoring Division, NOAA Earth System Research Laboratory

E-mail: james.h.butler@noaa.gov

Phone: 303-497-6898

IF DIFFERENT THAN ABOVE: PUBLIC INFORMATION/MEDIA CONTACT PERSON: Theo Stein

Title: NOAA Boulder Public Affairs Officer

E-mail: theo.stein@noaa.gov

Phone: 303-497-6288

1. SUMMARY TITLE OF NOMINATION: (20 words maximum please – this will be what is used in CO-LABS' media communications and descriptions)

Discovering a major violation of the most successful international treaty, the Montreal Protocol on Substances that Deplete the Ozone Layer

2. NAME OF PRINCIPAL INVESTIGATOR OR TEAM BEING NOMINATED - attach summary CV(s) if applicable. (Please be clear with the name(s), contact information and titles of those who should be listed – these will be the names recognized in any print and online communications about the nomination. We have a general request to keep the listed PIs to around 6 or less if possible)

Stephen A. Montzka (PI) and co-authors from the NOAA Global Monitoring Division (Brad D. Hall and James W. Elkins); the NOAA Chemical Sciences Division (Robert W. Portmann, John S. Daniel); and the Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder (**Geoff S. Dutton (PI)**, Pengfei Yu, **Eric Ray (PI)**, Debra Mondeel, Carolina Siso, David Nance, Lei Hu, Fred Moore, Ben R. Miller).

3. BRIEF DESCRIPTION: (300 words or less)

Emissions of CFC-11, one of the main chemicals responsible for the Antarctic ozone hole, are on the rise—indicating a violation of the world's most successful international protocol, the Montreal Protocol on Substances that Deplete the Ozone Layer. Because ozone in the stratosphere acts like sunscreen—shielding the planet from ultraviolet radiation that causes skin cancer and damages plants—governments, industry, and the public have made a sustained global effort for more than 30 years to remedy the problem.

In a 2018 *Nature*¹ study, NOAA scientist Stephen Montzka, with colleagues from the NOAA Global Monitoring and Chemical Sciences Divisions and the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder, discovered an unexpected global increase in emissions of this potent ozone-depleting gas beginning in 2013, with contributions apparently from eastern Asia. The results imply outlaw production of the chemical.

A follow up paper published in *Nature*² in 2019, by 32 authors from NOAA, CIRES, NASA, and research groups from six countries, reaffirmed the findings of the original study and presented strong evidence that China was violating the Montreal Protocol.

The announcement raised alarm worldwide. According to scientists writing in the *Bulletin of the Atomic Scientists*, "If not stopped quickly, the unexpected, unreported ... emissions of CFC-11 threaten to delay recovery of the ozone layer by nearly a decade, and set back the recovery of the Antarctic ozone hole by up to 30 years".³



Figure 1. At the 41st Open-Ended Working Group of the Parties to the Montreal Protocol in Bangkok, Thailand in July, 2019, Dr. Montzka described how the observational evidence obtained by the NOAA and CIRES team suggests a violation of the Montreal Protocol.

In response to this team’s work, the international body that oversees the Montreal Protocol has been working to better understand the problem, incorporating input and advice from its main advisory bodies into an effective global response. Furthermore, the Chinese government has presented a national-scale plan to reinvigorate their efforts to comply with the Protocol.

¹[Montzka](#), S.A., G.S. Dutton, P. Yu, E. Ray, R.W. Portmann, J.S. Daniel, L. Kuijpers, B.D. Hall, D. Mondeel, C. Siso, D.J. Nance, M. Rigby, A.J. Manning, L. Hu, F. Moore, B.R. Miller, J.W. Elkins, An unexpected and persistent increase in global emissions of ozone-depleting CFC-11, *Nature*, 557, 413-417 (2018).

²[Rigby](#), M, [S. Park](#)...S Montzka and 29 others, Increase in CFC-11 emissions from eastern China based on atmospheric observations, *Nature*, 569, 546–550 (2019).

³<https://thebulletin.org/2018/09/unexpected-unreported-and-so-far-unexplained-emissions-of-cfc-11>

4. DESCRIBE THE BACKGROUND AND CONTEXT SHAPING THE NEED AND INTEREST IN THIS RESEARCH. (700 words or less)

The stratospheric ozone layer filters out harmful ultraviolet radiation, which is associated with an increased prevalence of skin cancer and cataracts, reduced agricultural productivity, and disruption of marine ecosystems.

In 1985, it was reported that anthropogenic chlorofluorocarbons (CFCs) were destroying stratospheric ozone and producing an “ozone hole” over the South Pole. In 1987, in response to this report, every nation on Earth signed the Montreal Protocol, an agreement to protect the stratospheric ozone layer by phasing out the production of ozone-depleting substances. This agreement has proven to be innovative and successful, and is the first treaty to achieve universal ratification.

Reversing this damage to Earth’s stratospheric ozone layer has required vigilance and persistence by many governmental, public and private organizations and industries across the globe for more than 30 years. Twice each year since 1987, delegates from all nations have convened under the auspices of the United Nations Ozone Secretariat to assess the Protocol’s continued effectiveness for ensuring ozone-layer recovery. That this body continues to meet and assess ozone-layer recovery speaks to the critical importance of the ozone layer for life on Earth and to the continued need for vigilance in guiding ozone layer recovery.

Despite these efforts and suggestions that the ozone layer problem has been solved, ozone depletion is nearly as bad today as it has ever been: full recovery is predicted in the future only if countries continue to adhere to the controls on ozone-depleting substances as outlined by the Montreal Protocol.

This team’s sustained, high-quality observations show that shortly after the 1987 ratification of the Montreal Protocol, atmospheric concentrations of the main ozone-depleting substances stopped increasing and subsequently began decreasing. CFC-11 concentrations, for example, began decreasing in the early 1990s.

Since then, the NOAA and CIRES researchers continued their global-scale measurements and worked diligently to improve their accuracy and precision, ensuring that they would be able to detect subtle changes in rates of concentration decline and in concentration gradients that might represent noncompliance with Montreal Protocol. The team understood that these improvements would allow them to answer key questions regarding ozone-depleting substances and the Montreal Protocol, such as: “Are the concentrations of these controlled substances changing as expected?” and “Do the results indicate that countries are complying with the Montreal Protocol controls?”

Within this context and the 2010 ban on global CFC production, the team’s next discovery was shocking: just a few years after the ban on CFC production, the atmospheric data indicated a slowdown in the decline of global CFC-11 concentrations. Given the ban on production, the rate of decline of CFC-11 concentrations should have been accelerating, yet the opposite was

happening. Once they made this discovery, the team set out to understand what was causing the slowdown in the decline of CFC-11 concentrations by carefully and objectively examining multiple clues and available evidence. The team ultimately concluded that this international environmental agreement was indeed being violated.

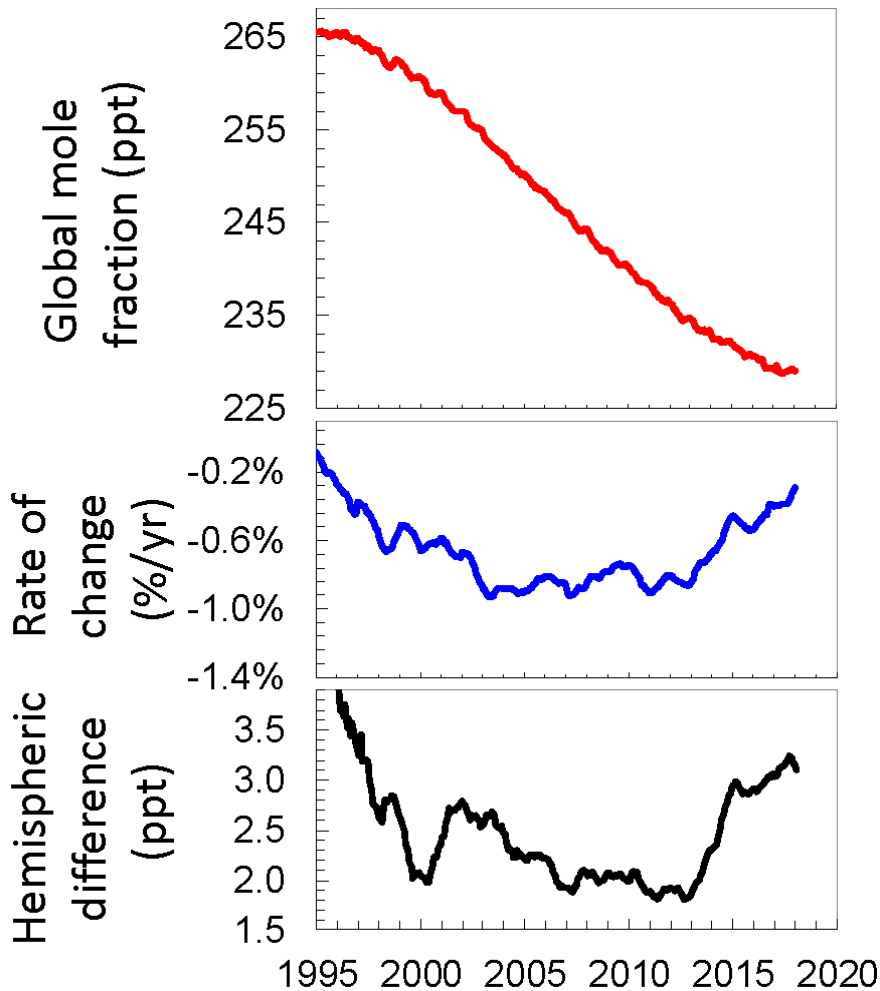


Figure 2. The NOAA/CIRES measurement record of CFC-11 shows its global concentration over time (top); the rate of change in that global concentration (middle); and the concentration difference in the northern versus southern hemisphere (bottom). The slowdown in the concentration decline beginning about 2013 is apparent in the middle and upper panels, and coincides with an increase in the difference in hemisphere mean concentrations. Because CFC-11 emissions predominantly come from the northern hemisphere, the increased hemispheric difference suggests an increase in CFC-11 emissions as the cause for the slowdown in the decline.

These unexpected emissions, if unchecked, could delay the recovery of the Antarctic Ozone Hole by about 20 years. Furthermore, this finding is significant because it shows that individuals who benefit financially and act collectively to violate the Protocol can significantly affect levels of atmospheric pollutants and the outcome of international environmental agreements.

This team's methods can act as a guide to finding illegal emissions of other banned or regulated substances, such as CO₂ and other greenhouse gases involved in climate change.

This discovery became an immediate topic of discussion at the United Nations and in other international and national agencies, and within the scientific community. A few months after those findings were made public, China made a commitment to the United Nations to immediately curtail the production of CFC-11 within their boundaries.

5. DESCRIBE THE COMPELLING FACETS OF THIS RESEARCH AND WHAT WAS THE ULTIMATE KNOWLEDGE AND INSIGHT DISCOVERED. (1200 words or less)

Initially, there were many potential explanations for why the decline in CFC-11 concentrations had slowed, ranging from the mundane (an instrumental artifact or measurement error) to the explosive: a country violating the Montreal Protocol by restarting production of CFC-11 despite the ban, leading to an increase in emissions. This team investigated all of these possibilities and more, using methodical, rigorous, and creative approaches.

Of the intricate forensics analysis used by the NOAA/CIRES team in this study, Piers Forster, a professor at the University of Leeds not connected with the work, said: “This new study is atmospheric detective work at its finest.” (*The Guardian*, May 16, 2018).

Ultimately, the evidence pointed to the explosive conclusion, as described below.

Given that the changes measured in the CFC-11 concentration decline and its hemispheric distribution were quite subtle, the team first reviewed their approach to measuring CFC-11, and demonstrated that the slowdown they were observing was not an artifact associated with some interference, but was a real change in the balance of CFC-11 sources and sinks.

Simply observing the slowdown was a testament to the skill and ability of the group to make highly consistent measurements over extended periods of time. But the value of communicating only this message to the world would be fairly insignificant if the underlying cause of the concentration slowdown was not identified. This was a critical piece, because changes in CFC-11 concentrations arise from an imbalance between two things: the rate at which CFC-11 is removed from the atmosphere (sinks) and the rate at which it is added to the atmosphere (emissions). Accordingly, the observed slowdown in the concentration decline could have been due to an increase in emission or a slowdown in the removal of CFC-11 from the atmosphere.

The team’s next task was to determine which process was responsible for the observed slowdown—a challenging task, since at first glance both possibilities seemed highly unlikely. A slowdown in the atmospheric removal of CFC-11 could potentially indicate an unusual shift in large-scale atmospheric chemical and physical processes. Such a change is predicted to occur as a result of increasing greenhouse gas concentrations, but only slowly over time. However, to imagine that emissions had increased a number of years after the global ban on production seemed equally unlikely.

The team took multiple creative approaches to determining the underlying cause of the slowdown in the decline of CFC-11 concentrations. The first involved modeling of the

atmosphere to understand how the CFC-11 concentration decline might have changed if emissions had simply remained constant over time. The researchers used highly complex 3-dimensional models of atmospheric processes in combination with global-scale meteorological data. The results suggested that some changes in atmospheric processes had indeed contributed to the observed slowdown, but it wasn't clear that these changes would persist into the future. Even more important was the team's conclusion that the changes in atmospheric processes in this state-of-the-art atmospheric model simulation did not explain all aspects of the concentration slowdown.

The conclusion from the 3-D modeling analysis suggested a non-zero contribution from changes in atmospheric processes. However, the possibility existed that the models weren't quantitatively accurate—and that the anomaly could be related entirely to a change in atmospheric processes, and not the result of a change in human behavior leading to increased emissions.

This led the team to examine the data for evidence of an emission increase independent of the 3-D modeling analysis. In this careful inspection of results from nearly a dozen remote atmospheric observatories, the researchers noticed that only results from the high-altitude site in Hawaii (Mauna Loa Observatory, or MLO) had changed over time in a very subtle way. That is, CFC-11 concentrations at MLO had become more variable by about 0.5 percent during autumn after 2012, as compared to earlier. Furthermore, the enhanced CFC-11 variability observed only after 2012 was closely mimicked by the concentrations of other industrially produced gases in pollution plumes reaching MLO.

In other words, slightly enhanced CFC-11 concentrations were observed in pollution plumes reaching MLO, and the only reason for this would be an increase of CFC-11 emissions in the source region for that pollution. This was the “smoking gun” indicating that CFC-11 emissions had indeed increased after 2012 and were contributing to the slowdown in its global concentration decline.

Knowing from previous studies that emissions from Asia can affect air reaching the MLO observatory during autumn, the team enlisted collaborators from the UK to analyze with sophisticated back-trajectory analyses the origin of the air masses that contained slightly elevated levels of CFC-11 and other human-emitted gases. This work confirmed that these pollution plumes had originated somewhere in eastern Asia.

These intricate analyses had clarified the picture as follows: CFC-11 emissions had increased in part because of increased emissions from eastern Asia. This explosive result potentially indicated an intentional violation of the Montreal Protocol. But there was one other important question remaining that was relevant to the issue of Protocol compliance: Was the emission increase associated with CFC-11 produced before the 2010 phase-out, or after? The protocol does not prohibit the use of banned chemicals, but only controls their production and international trade. Given that there is a large reservoir of old, pre-phase-out CFC-11 in refrigeration and insulating foam in refrigerators and buildings, it was possible that the increase in emissions was simply the result of old CFC-11 escaping more rapidly from existing refrigerators and foams. This was the last critical insight provided by these scientists, as they

surmised that the escape rate from these old CFC reservoirs would have had to double in just a few years to explain the increased emissions.

The team concluded that this was not possible, and that the increased emission had to be the result of new production since 2013, in clear violation of the Montreal Protocol.

6. DESCRIBE ANY CREATIVE, UNIQUE AND/OR EFFECTIVE PARTNERSHIPS, TEAMS OR COLLABORATIONS THAT INFLUENCED THIS RESEARCH. *(1000 words or less)*

To investigate potential reasons for the observed slowdown in the decline of CFC-11 concentrations, the Global Monitoring Division measurement team enlisted the help of the NOAA Chemical Sciences Division (CSD) team's modeling expertise. CSD scientists (Yu, Portmann, Ray, Daniel) used many different models (ranging from box to 3D chemistry-climate models) to test whether the CFC-11 changes that were observed could have occurred from a process other than increased emissions—for example, as a result of a slowdown in CFC-11 atmospheric removal or a change in the mixing of air between the troposphere and stratosphere. This collaboration substantially strengthened the research, and the scientists were able to put forth a robust scientific argument supplying irrefutable evidence for an emission increase. The result allowed the United Nations, other agencies, and governments around the world to focus on the implications of these results, rather than their validity.

The insights that resulted from the 3-dimensional modeling work done for this project are leading to additional groundbreaking research into the impact of atmospheric oscillations such as the El Niño-Southern Oscillation and the Quasi Biennial Oscillation on CFC-11 atmospheric lifetimes. A thorough analysis of possible shortcomings in the 3D chemistry-climate models by this team has led to further understanding of how these complex models work and how to improve them. This is a valuable additional outcome of the CFC-11 program.

The profound result enabling the attribution of increased CFC-11 emissions to eastern Asia was obtained with the assistance of Dr. A. Manning at the UK Met office. As the world's expert in understanding air motions and analyses that enable the attribution of pollution plumes to specific surface regions, his input was key to this important conclusion of the research. The assistance of Prof. M. Rigby was also essential to the estimates of global emissions. His methods for deriving these emissions were critical for validating the global emission trends over time and supported the evidence for increasing emissions.

As discussed above, the team also was faced with the difficult issue of determining if the increased emission was due to increased releases from CFC-11 in older insulating foams and refrigerating systems, or if it was actually due to new production that would represent a violation of the Montreal Protocol. To address this issue, the team enlisted the help of Prof. L. Kuijpers of The Netherlands, a scientist with expert knowledge of industry activities and emissions of halocarbons from foams and other appliances. With his expertise, the team was able to argue that the evidence necessitated new production of CFC-11, a clear violation of the Protocol. This conclusion has since been supported by the wider community of industry experts in their preliminary reports to the UN Ozone Secretariat and the Parties to the Montreal Protocol.

7. HOW HAS THIS RESEARCH BEEN APPLIED, UTILIZED, COMMERCIALIZED OR OTHERWISE ADOPTED OUTSIDE YOUR LAB? *Consider: specific problem(s) mitigated, public policy changes, enhanced public understanding, new protocols within fields of scientific research, etc. (1000 words or less)*

The methodical detective work undertaken by these scientists allowed them to announce to the world that despite indications of success, the Montreal Protocol was in fact being breached in a substantial way by a country in eastern Asia. If left unchecked, this breach would have reversed the progress made to date towards healing the ozone layer. This study has had numerous repercussions around the world.

Immediately after the team's paper was published, *The New York Times* and the UK's Environmental Investigation Agency began their own on-the-ground investigations into the source of the breach. Those efforts provided qualitative confirmation that CFC-11 was being extensively used and produced in China, despite reporting by Chinese authorities to the UN's Ozone Secretariat that CFC production had been eliminated in China in about 2008. Clearly, the NOAA/CIRES team's results had identified some previously unrecognized illicit activities that were thwarting the global effort to heal the ozone layer

The UN Ozone Secretariat responded rapidly with a call to address the issue. In the Executive Secretary's opening statement to the international delegations attending the meeting of the Parties to the Montreal Protocol in July of 2018, the team's CFC-11 work was highlighted as follows:

"New findings from a study released in May in the journal Nature report that emissions of CFC-11, the second most abundant ozone-depleting gas controlled by the Montreal Protocol, have unexpectedly increased in recent years, despite a global phase-out of production since 2010.

If these increased emissions continue unabated, they will slow down the recovery of the ozone layer. It is therefore critical that we take stock of this science, identify the causes of these emissions and take necessary action.

We, collectively, as governments, industries, civil society, Implementing Agencies, and institutions of the Protocol, all have a deep stake in sorting out this issue, in finding the source of the emissions and abating them.

We cannot relax our vigilance for a second. We cannot let this go unaddressed."

The UN Ozone Secretariat has since dedicated major parts of every recent full-Party meeting to analyze the factors involved in the violation of the Protocol related to CFC-11. Meetings including delegations from all countries of the world have been held in November 2018 in Ecuador, and in March 2019 in Thailand; discussions of the CFC-11 issue will continue in the November 2019 meeting of the Parties in Rome. The initial response of the Parties has been to ask for additional information so that they can decide on effective and appropriate action to

both solve the CFC-11 problem and, as the Ozone Secretariat indicated in her opening statement in Ecuador:

“...at the same time, we should make the challenge of CFC11 a big opportunity for strengthening our treaty.”

In other words, this team’s work has resulted directly in a reassessment, by the Ozone Secretariat and the Parties to the Montreal Protocol, of the Montreal Protocol itself, to ensure that similar breaches of the Protocol will not arise in the future as other classes of chemicals are phased out. In future years the Protocol will phase out and phase down production and trade of additional chemical classes to further facilitate ozone recovery and lessen the Protocol’s impact on climate change. The specific shortcoming of the Protocol that the team’s work has highlighted was the absence of a mechanism to ensure that a mandated phase-out was sustained after it was initially documented by independent inspectors.

Another significant outcome of this team’s work is that advisory panels to the UN Ozone Secretariat and the Parties to the Montreal Protocol have been enlisted to prepare in-depth reports concerning increased CFC-11 emission and production. After planning meetings in Vienna in March 2019 to outline these reports, scientists and industry experts from around the world (including some from the NOAA/CIRES team) are currently finalizing them for delivery to the Ozone Secretariat and the Parties to the Protocol in November 2019.

The follow-up 2019 Rigby et al. *Nature* paper confirmed the initial paper’s results and added an important refinement: China was responsible for at least half of the global emissions increase. While the first paper suggested China as the culprit because it is the most significant chemical producer in eastern Asia, this second paper confirmed China’s dominant role as the source of much of the problem.

With the scientific evidence pointing to China as a significant contributor to this global-scale problem, there has been a substantial Chinese response. Country-wide searches and crackdowns on CFC use in the country have been conducted. Furthermore, an international workshop (attended by Montzka) explored a range of actions China might take to address this issue. A far-reaching national-scale plan to address the increase in CFC-11 emissions was developed and includes renewed efforts to identify and halt illegal production and use of CFC-11 within the country; improve the tracking of chemicals used to produce CFC-11; the creation of six new measurement facilities to track use of CFC-11 in new commercial products; and the creation of a national atmospheric measurement network for the detection and quantification of CFC-11 emissions across China⁴.

This outcome, which can be attributed directly to this team’s long-term and accurate measurements of CFC-11 in the atmosphere and their skill in communicating this critical information to a global audience, will benefit people worldwide for generations to come.

Finally, the Montreal Protocol has mechanisms to encourage compliance or, lacking that, enact penalties. Thus far, a “non-compliance” decision has not been enacted towards China, but as a

developing country, China had a request pending to the funding branch of the Montreal Protocol for millions of dollars in assistance to meet other compliance deadlines in the Montreal Protocol. As of Fall 2019, the funding arm has decided to withhold tens of millions of dollars from China because of the CFC-11 issue discovered by this NOAA/CIRES team.

⁴Cyranoski, D. China feels the heat over rogue CFC emissions. *Nature, In Focus News*, 571, 309-310 (2019).

8. OPTIONAL: *Any related awards, recognitions and context for this research:*

A. The original findings in the 2018 Montzka et al. *Nature* paper have been the subject of **6270** print, radio, and internet mentions. Altmetric, the service that ranks the online attention received by scientific papers, currently rates the 2018 *Nature*¹ paper in the **99th percentile and ranked 4th of 861 for global impact** of articles of similar age published in *Nature*, and **22nd of 270,862** tracked articles of a similar age published in all journals. It has an overall Altmetric score of 2214, a value putting this paper within the top 100 of all scientific papers published during 2018.

B. The team's 2019 Rigby et al. *Nature* paper identifying China as a source of the CFC-11 emissions was the subject of more than **16,000** print, radio and internet mentions. Altmetric, the online activity-tracking service, currently rates the 2019 *Nature*² paper in the **98th percentile and ranked 12th of 894 for global impact** of articles of similar age published in *Nature*, and **78th of 251,076** tracked articles of a similar age published in all journals. It has an Altmetric overall score of 1399.

These statistics underscore the importance of this research and its global reach and significance.

C. Geoff Dutton, Lei Hu, Ben Miller, Debra Mondeel, Fred Moore, David Nance, Eric Ray, Carolina Siso, and Pengfei Yu, received a CIRES Outstanding Performance Award in 2019 for their role in the 2018 Montzka et al. *Nature* paper: These CIRES scientists provided the analytical and interpretive foundations of the paper that has identified substantial unreported emissions of trichlorofluoromethane (CFC-11), a major ozone-depleting substance.

D. The global scientific community assesses the state of the ozone layer and ozone science once every four years in a report commissioned by the Ozone Secretariat to inform the Parties to the Montreal Protocol. The 2018 Assessment addressed the issue of the unusual and unexpected increase in CFC-11 emissions and the potential impacts on the ozone layer were discussed in depth. The report confirmed all of the major conclusions of the Montzka et al. *Nature* paper and the work of this NOAA/CIRES team.

World Meteorological Organization, *Scientific Assessment of Ozone Depletion: 2018*, Global Ozone Research Monitoring Project—Report No. 58, 588 pp., Geneva, Switzerland, 2018; online at: <http://ozone.unep.org/scence/assessment/sap>.

The following is a full list of NOAA and CIRES researchers involved in this project.

Stephen A. Montzka (NOAA)

Brad D. Hall (NOAA)

James W. Elkins (NOAA)

Robert W. Portmann (NOAA)

John S. Daniel (NOAA)

Geoff S. Dutton (CIRES)

Pengfei Yu (CIRES)

Eric Ray (CIRES)

Debra Mondeel (CIRES)

Carolina Siso (CIRES)

David Nance (CIRES)

Lei Hu (CIRES)

Fred Moore (CIRES)

Ben R. Miller (CIRES)

Once completed, please transfer to PDF format for submission.

If you have existing media regarding this research, please provide this to CO-LABS to assist with our outreach communications regarding your nomination. As we receive your nomination we will schedule your interview for our podcast and press releases.

Nominations are due to Dan Powers, CO-LABS Executive Director at dan@co-labs.org by 5:00 pm on Monday October 14, 2019.

For questions or information, contact Dan Powers at dan@co-labs.org or 720-389-0455. Winners will be notified by Wednesday, October 23, 2019.

The Governor's Awards presentation and reception will be held on Tuesday, November 12, 2019, 5:00 – 9:00 pm at the Denver Museum of Nature and Science.

Hosted by:



About CO-LABS:

Started in 2007, CO-LABS is a non-profit consortium of federal laboratories, research institutions, businesses and economic development organizations that provide financial and in-kind support for programs that promote the retention and expansion of Colorado's federally-funded scientific resources. Through events, economic analyses, strategic communications and networking activities we work to:

- **PROMOTE** Colorado as a global leader in research and technology
- **EDUCATE** the public about federal research labs' and institutions' impact, and importance of sustained funding for research
- **CONNECT** the labs, universities, economic development organizations and businesses to facilitate partnerships and technology transfer

To learn more, visit www.CO-LABS.org.

Stephen A. Montzka

I. Education:

- Ph.D. 1988 Analytical Chemistry, University of Colorado, Boulder.
B.S. 1983 Summa Cum Laude with Highest Honors in Chemistry, St. Lawrence University.

II. Employment:

- 3/91-Present Research Chemist, NOAA Earth System Research Laboratory's Global Monitoring Division. Dr. Montzka is the project leader of the Chlorofluorocarbons Alternative Monitoring Project and is responsible for ongoing global atmospheric measurements of approximately 30 chemicals at multiple remote sites across the globe that influence climate, stratospheric ozone, and air quality. These data are integral to NOAA's Annual Greenhouse Gas Index and the Ozone-Depleting Gas Index, which are internationally recognized metrics of the atmospheric abundance of climate-active and ozone-depleting gases. The data obtained from the program he leads are regularly highlighted in international scientific assessments related to ozone depletion and climate commissioned by the World Meteorological Organization and the Intergovernmental Panel on Climate Change.
- 1/89-3/91 National Research Council Post-Doctoral Fellow, Aeronomy Laboratory (now Chemical Sciences Division), NOAA.

III. Awards and Honors

- 2018 Named a Fellow of the American Geophysical Union
2016 Elected a member of the International Ozone Commission
2016 Excellence in Refereeing Editor's Citation by GRL
2015 Nominated into the Montreal Protocol's Who's Who
2014 Team Member, Colorado Governor's Award for High-Impact Research
2012 Excellence in Refereeing Editor's Citation by JGR-A
2011 Elected a Fellow of CIRES, Univ. of Colorado
2008 U.S. Department of Commerce Silver Medal
2007 Excellence in Refereeing Editor's Citation by GRL
2008 NOAA Administrator Award
2007 U.S. EPA Stratospheric Ozone Protection Award
2000 NOAA Research Employee of the Year
1997 U.S. Department of Commerce Silver Medal
1996-2011 Awarded NOAA Outstanding Scientific Paper of the Year Award (nine times).

1994, 1995, 2003	NASA Group Achievement Awards for separate field missions.
1992, 1993, 1997	U.S. Department of Commerce, NOAA Certificate of Recognition.
1989, 1990	National Research Council Post-Doctorate Fellowships
1983, 1984	Colorado Doctoral Fellowships
1982	Phi Beta Kappa

IV. Participation in National and International Scientific Assessment Reports:

1. WMO/UNEP Scientific Assessment of Ozone Depletion reports:

For the 2018 Report:

Coordinating Lead Author of Chapter 2 (with G. Velders)
Contributor, Chapter 1 and Chapter 6

For the 2014 Report:

Review Editor, Chapter 1;
Co-author of the “Twenty questions and answers about the ozone layer: 2014 update.

For the 2010 Report:

Coordinating Lead Author of Chapter 1 (with S. Reimann)
Co-Author, Chapter 5

For the 2006 Report:

Co-Author, Chapter 1
Contributor, Chapter 8
Liaison for Chapters 1 and 2, and for Chapters 1 and 8.

For the 2002 Report:

Lead Author (with P. Fraser), Chapter 1

For the 1998 Report:

Co-Author, Chapter 2
Contributor, Chapter 1

2. IPCC Working Group 1 Climate Change Reports:

Third Assessment Report (2001), *Climate Change 2001, The Scientific Basis*,
Contributing Author, Chapter 4

Fourth Assessment Report (2007), *Climate Change 2007, The Physical Science Basis*, Contributing Author, Chapter 2

Fifth Assessment Report (2013), *Climate Change 2013, The Physical Science Basis*, Contributing Author, Chapter 2 (and reviewer)

3. WMO/WCRP SPARC Reports:

- a. Assessment of Stratospheric Aerosol Properties (2006): Author, Chapter 2
- b. Lifetimes of Stratospheric Ozone-Depleting Substances, Their Replacements, and Related Species: Co-Author, Chapter 4 (December 2013)
- c. The Mystery of Carbon Tetrachloride: Author (July 2016)

4. Climate Change Science Plan Synthesis and Assessment Product 2.4 (2008):

Convening Lead Author, Chapter 2

5. TEAP/UNEP Task Force on Emissions Discrepancies Report (2006):

Lead Author and co-Chair

6. **IPCC/TEAP Special Report** on Safeguarding the Ozone Layer and the Global Climate System (2005): Contributing Author, Chapter 1 and Chapter 2 (and expert reviewer)
7. **UNEP Synthesis Report** “HFCs, A critical link in protecting climate and the ozone layer”, contributor, 2011.
8. **IPCC Emissions Gap Report 2012**: Contributing Author, Chapter 1

V. Peer-Reviewed Publications since 2014 (out of 175; H-index = 54):

1. Hossaini, R. E. Atlas, S.S. Dhomse, M.P. Chipperfield, P.F. Bernath, A.M. Fernando, J. Mühle, A.A. Leeson, S.A. Montzka, W. Feng, J.J. Harrison, P. Krummel, M.K. Vollmer, S. Reimann, S. O’Doherty, D. Young, M. Maione, J. Arduini, C.R. Lunder, Recent trends in stratospheric chlorine from very short-lived substances, *J. Geophys. Res.*, 124, 4, 2318-2335, <https://doi.org/10.1029/2018JD029400>, 2019.
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VI. Special Projects/Field Missions:

1. Project leader, the Chlorofluorocarbons Alternatives Measurement Project—flask analysis by GCMS (1991-present). (NOAA)
2. Co-Principle Investigator with L. Hu, on "Estimating U.S. emissions of non-CO₂ greenhouse gases using long-term atmospheric observations," 2019-2020. (GIST.earth, LLC)
3. Co-Principle Investigator with L. Hu, on "More precisely locating sources of the unexpected increase in CFC-11 emissions using HIPPO and ATom data," 2019-2020. (NASA)
4. Co-Principle Investigator with C. Sweeney, for flask sampling during the NASA-funded Atmospheric Tomography Experiment (ATom), 2016-2018. (NASA)
5. Co-Investigator with J. Elkins and F. Moore on the NSF-funded High Performance Instrumented Airborne Platform for Environmental Research (HIAPER) Pole-to-Pole Observations of Greenhouse Gases (HIPPO 1 to 5) mission, 2008-2012. (NSF)
6. Co-Investigator with S. Lehman and J. Miller on "Quantifying regional emissions ratios using ¹⁴CO₂" (NOAA; 2012-2015). (NOAA)
7. Flask sampling on the NOAA-P3 as part of the NOAA Aerosol, Radiation, and Cloud Processes affecting Arctic Climate mission, Spring 2008.
8. Co-PI, with P. Tans and D. Yakir on a U.S.-Israel Bi-national Science Foundation Grant, 2005-2008.
9. GCMS flask measurements for Trans-Siberian Railway Observations into the Chemistry of the Atmosphere, TROICA-8, Russia, March-April 2004.
10. Instrument assistance onboard NASA's DC-8 during the SAGE II Ozone Loss and Validation Experiment, Kiruna, Sweden, January 2003.
11. Surface firn air sampling and firn-air sampling tube installation, South Pole, January 2001.
12. Instrument installation onboard NOAA's R.H. Brown in preparation of the Gas Exchange Experiment, Miami, May 1998.

13. Instrument assistance during NASA's Observations of the Middle Stratosphere Balloon mission, Ft. Sumner, New Mexico, September 14-19, 1996.
14. Airborne Southern Hemisphere Ozone Experiment / Measurements for Assessing the Effects of Stratospheric Aircraft, Christchurch, New Zealand, September-October 1994.
15. Bromine Latitude Air-Sea Transect, onboard the NOAA Discoverer, January 1994.
16. Stratospheric Photochemistry and Dynamics Experiment, San Jose, May 1993.
17. Rural Oxidants in the Southern Environment II, Alabama, June-July 1992.
18. Rural Oxidants in the Southern Environment I, Alabama, June-July 1990.
19. Flasks have been analyzed as part of multiple firn-air sampling in Antarctica (South Pole-2000, -2008, -2015; Siple Dome-1996; Megadunes-2004; and WAIS-2005) and in Greenland (Tunu-1996, Summit-2004 through 2008, Rennland-2015).

VII. Invited Presentations since 2014 (out of 44):

1. **Scheduled:** "On science informing international policy: Are emissions of a banned ozone-depleting substance really increasing?" Invited colloquium speaker at the University of Toronto Department of Physics, 27 February, 2020.
2. "On science informing international policy: Are emissions of a banned ozone-depleting substance really increasing?" Invited talk presented at the NCAR ACOM seminar series, 26 August, 2019.
3. "New insights into the source of increased CFC-11 emissions", presented as a side event at the 41st Open-Ended Working Group of the Montreal Protocol on Substances that Deplete the Ozone Layer, July 2019, Bangkok, Thailand.
4. "Atmospheric measurements of CFC-11 through 2018: Are global CFC-11 emissions back on the decline?" Invited talk presented at the International Symposium on the unexpected increase in emissions of ozone-depleting CFC-11, 25-27 March, 2019.
5. "On science informing international policy: Are emissions of a banned ozone-depleting substance really increasing?" Invited talk presented at the University of Vienna seminar series, 22 March, 2019.
6. "A scientific understanding of recent atmospheric observations of CFC-11", invited talk presented at the International workshop on capacity building for the implementation of the Montreal Protocol in China, 18 March 2019, Beijing, China.
7. "Towards a further understanding of the magnitude and underlying cause for the recent increase in global CFC-11 emission", invited talk at the 2018 Fall AGU meeting, Washington, D.C., December 12, 2018.
8. "Atmospheric Science insights from long-term global-scale air sampling", invited talk at the New Fellows in Atmospheric Sciences Session at the 2018 Fall AGU meeting, Washington, D.C., December 12, 2018.
9. "Updates to our understanding of the recent increase in CFC-11 emissions", presented as a side event at the 30th Meeting of the Parties of the Montreal

Protocol on Substances that deplete the Ozone Layer, November 2018, Quito, Ecuador.

10. "The evidence for increasing emissions of CFC-11", presented as a side event at the Open-Ended Working Group of the Montreal Protocol on Substances that deplete the Ozone Layer, July 2018, Vienna, Austria.
11. "Methyl Bromide in the Atmosphere—A Scientific Overview and Update", an invited plenary lecture at the 2017 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, San Diego, CA, 13 November, 2017.
12. Tracking global changes in greenhouse gases concentrations at NOAA: What have we learned? Presented at the 2nd International Technical Workshop on Climate Risk, Kennebunkport, Maine, Oct 2017 (remotely presented).
13. The value and limitations of global air-sampling networks for improving our understanding trace gas behavior, invited talk at the 2016 Fall AGU meeting, San Francisco, CA, December 2016.
14. "Probing broad-scale atmospheric observations for clues to unraveling the carbon tetrachloride conundrum", invited Keynote speaker at the SPARC Activity Workshop: "Solving the Mystery of Carbon Tetrachloride", Dubendorf, Switzerland, 4-5 Oct, 2015.
15. "Methyl Bromide in the Atmosphere—A Scientific Overview and Update", an invited plenary lecture at the 2015 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, San Diego, CA, 9 November, 2015.
16. "Characterizing regional- to global-scale concentrations of short-lived halocarbons", presented by invitation at Harvard University's Environmental Sciences and Engineering Spring 2015 Seminar Series, 20 Feb 2015.
17. "Science of HFCs: High HFC growth from scenarios confirmed by atmospheric sampling", presented by invitation as a side event to the 26th Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, 18 Nov 2014, Paris, France.
18. "Recent trends in global concentrations and emissions of hydrochlorofluorocarbons and hydrofluorocarbons", presented by invitation at EMPA, 12 May 2014, Duebendorf, Switzerland.

VII. Conference Proceedings, Technical Reports, and Book Chapters (since 2009; out of 19):

1. Montzka, S.A., Tracking global changes in greenhouse gas concentrations, Chapter 2 in: *The perils of climate risk: The people and the science*, Cambridge Scholars Publishing, UK, C. LaBlanc, Ed., 2019.
2. Montzka et al., CGBAPS 2011-2013 report, 2018.
3. Montzka, S.A., C. Siso, D. Mondeel, B. R. Miller, B. D. Hall, J. W. Elkins, and J. H. Butler, Flask measurements at CGBAPS by the HATS Group of NOAA/ESRL/GMD, In: *Baseline Atmospheric Program Australia 2009 - 2010*, Australian Bureau of Meteorology and CSIRO Marine and Atmospheric Research, Melbourne, 51-55, 2014.

4. Fischer, M.L., Jeong, S., Keeling, R., Andrews, A.E., Bianco, L., Dlugokencky, E., Lehman, S.J., Miller, J.B., Montzka, S., Wilczak, J., and P. Tans (2012) "Atmospheric Measurements and Modeling for Verification of AB-32 Mandated Emissions Reductions", California Energy Commission CEC-XXX, Nov. 2012 (69 pp.).
5. Montzka, S.A., HFCs in the Atmosphere: Concentrations, Emissions and Impacts, Proceedings for ASHRAE 2012 annual meeting, 2012.
6. Montzka, S.A., Non-CO₂ gases influencing ozone and climate. Chapter 2 in *Stratospheric Ozone Depletion and Climate Change*, R. Müller, ed., Royal Society of Chemistry, ISBN: 978-1-84973-002-0, 2012.

IX. Panels and Committees Served on:

1. Consulting expert to the WMO/UNEP Technology and Economic Assessment Panel Task Force on Unexpected Emissions of CFC-11, 2019.
2. U.S. representative (with K. Jucks, NASA) to the 10th UNEP meeting of the Ozone Research Managers of the parties to the Vienna Convention of the Montreal Protocol (Geneva, March, 2017).
3. U.S. representative (with K. Jucks, NASA) to the 9th UNEP meeting of the Ozone Research Managers of the parties to the Vienna Convention of the Montreal Protocol (Geneva, May, 2014).
4. CIRES Executive Committee Member, 2012-2013
5. Review panel member of proposals for the German "Conference of Science-driven evaluation of Large Research Infrastructure Projects for a National Roadmap (Pilotphase)", 16-17 April, 2012, Berlin, Germany.
6. NASA UARP Proposal Review Panel member, 19-20 Oct, 2011.
7. European Commission Research Directorate-General Starting Grants Evaluation Panel for Earth System Science, August, 2007.

X. Professional Societies:

American Geophysical Union
 American Association for the Advancement of Science

XI. Supervisor to:

Dr. Lei Hu, CIRES Research Scientist II (2012-present)
 Ms. Carolina Siso, CIRES Associate Scientist II (2007-present)
 Dr. Mindy Nicewonger, NRC Postdoctoral Fellow (*starting* Oct. 2019)

XI. Recent extended visitors to the Montzka lab:

Prof. Dan Yakir, Weizmann Institute, Israel, summer of 2012 (CIRES)
 Prof. Michela Maione, Univ. of Urbino, Italy, summer of 2013
 Prof. Michela Maione, Univ. of Urbino, Italy, summer of 2014

Prof. Manual Gloor, Univ of Leeds, UK (with S. Benjamin and J. Miller), summer of 2014 (CIRES).

Stijn Naus, as a graduate student, Univ. Wageningen, summer 2017.

Prof. William Sturges, Univ of East Anglia, Fall 2018.

XII. Selected media coverage of Montzka and HATS group activities:

Related to the 2018 paper in *Nature* on CFC-11, viewable [here](#) (Montzka et al.), and the 2019 follow-up paper in *Nature* on CFC-11 [here](#) (Rigby et al.).

- <https://www.nytimes.com/2018/05/16/climate/ozone-layer-cfc.html?partner=rss&emc=rss>
- <https://www.nytimes.com/2019/05/22/climate/china-cfcs-banned-chemicals-ozone.html>
- <https://www.theguardian.com/environment/2018/may/16/mysterious-rise-in-banned-ozone-destroying-chemical-shocks-scientists>
- <https://www.bbc.com/news/science-environment-48353341>
- https://www.washingtonpost.com/news/energy-environment/wp/2018/05/16/someone-somewhere-is-making-a-banned-chemical-that-destroys-the-ozone-layer-scientists-suspect/?utm_term=.a2086b739b1b
- <https://podcast-a.akamaihd.net/mp3/podcasts/quirksaio-Qt4NsX7T-20180525.mp3> (extended ratio interview)

Other media coverage:

- <https://www.climate.gov/tags/steven-montzka>
- or <https://www.climate.gov/news-features/climate-tech/bottled-air-all-over-world-tells-story-ozone-depleting-gases-and-their>
- <http://cires.colorado.edu/news/press/recent-adjustments-montreal-protocol>
- <http://research.noaa.gov/News/NewsArchive/LatestNews/TabId/684/ArtMID/1768/ArticleID/10744/NOAA-Scientists-Contribute-to-2014-Ozone-Depletion-Assessment.aspx>
- http://www.esrl.noaa.gov/news/quarterly/fall2009/profile_stephen_a_montzka.html

CIRES Fellow's web page:

<http://cires.colorado.edu/about/organization/fellows/stephen-montzka/>

Geoffrey S. Dutton

325 Broadway, GMD1
Boulder, CO 80305

Geoff.Dutton@noaa.gov
(303)-497-6086

Education:

1992 B.S. Engineering Physics, University of Colorado, Boulder

Professional Experience:

2004-Present Associate Scientist III at NOAA/GMD employed by the Cooperative Institute for Research in the Environmental Sciences (CIRES), Boulder, Colorado
1992-2004 Associate Scientist II at NOAA/GMD and CIRES, Boulder, Colorado
1990-1992 University of Colorado Undergraduate Research Opportunities Program

Research / Field Work Experience

- Project lead on the in-situ halocarbons program with 20 years of continuous measurements at NOAA baseline observatories.
- Support of multiple aircraft campaigns
- Instrument and software development

Honors and Awards:

2019 CIRES Outstanding Performance Award
2017 NASA Group Achievement Award for the POSIDON campaign
2016 NASA Group Achievement Award for the ATTREX campaign
2013 Bronze Team Medal -- *The successful demonstration of the Global Hawk Unmanned Aircraft Systems for NOAA's Climate Goal during the GloPac mission.*
2009 First place in NOAA/OAR photo contest
2009 Silver Team Medal for NOAA for Annual Greenhouse Gas Index
2008 NASA Group Achievement Award for TC4 campaign
2007 Nobel Peace Prize – Contributing author to the Intergovernmental Panel on Climate Change (IPCC)
2007 EPA Stratospheric Ozone Protection Award
2006 Bronze Team Medal for NOAA Unmanned Aerial Systems Demo
2003 NASA Group Achievement Award for CRYSTAL/FACE campaign
2002 CIRES Outstanding Performance Award
2000 NOAA/CMDL Director's Award for Outstanding Scientific Support
1998 NOAA Outstanding Science Papers of the Year -- *Quantifying transport between the tropical and mid-latitude lower stratosphere.*
1998 NASA Group Achievement Award for POLARIS campaign
1996 NASA Group Achievement Award for ASHOE/MAESA campaign
1994 NASA Group Achievement Award for SPADE campaign

Published dataset:

- Chromatograph for Atmospheric Trace Species: <http://doi.org/10.7289/V5X0659V>

Publications (chronological order):

Rigby, M., S. Park, T. Saito, L. M. Western, A. L. Redington, X. Fang, S. Henne, A. J. Manning, R. G. Prinn, G. S. Dutton, P. J. Fraser, A. L. Ganesan, B. D. Hall, C. M. Harth, J. Kim, K.-R. Kim, P. B. Krummel, T. Lee, S. Li, Q. Liang, M. F. Lunt, S. A. Montzka, J. Mühle, S. O'Doherty, M.-K. Park, S. Reimann, P. K. Salameh, P. Simmonds, R. L. Tunnicliffe, R. F. Weiss, Y. Yokouchi and D. Young, (2019), [Increase in CFC-11 emissions from eastern China based on atmospheric observations](#), *Nature*, 569, 7757, 546-550, 10.1038/s41586-019-1193-4

Zhou, Minqiang, Bavo Langerock, Corinne Vigouroux, Pucai Wang, Christian Hermans, Gabriele Stiller, Kaley A. Walker, Geoff Dutton, Emmanuel Mahieu and Martine De Mazière, (2018), [Ground-based FTIR retrievals of SF6 on Reunion Island](#), *Atmospheric Measurement Techniques*, 11, 2, 651-662, 10.5194/amt-11-651-2018

Wells, Kelley C., Dylan B. Millet, Nicolas Bousseres, Daven K. Henze, Timothy J. Griffis, Sreelekha Chaliyakunnel, Edward J. Dlugokencky, Eri Saikawa, Gao Xiang, Ronald G. Prinn, O&, apos, Simon Doherty, Dickon Young, Ray F. Weiss, Geoff S. Dutton, James W. Elkins, Paul B. Krummel, Ray Langenfelds and L. Paul Steele, (2018), [Top-down](#)

- [constraints on global N₂O emissions at optimal resolution: application of a new dimension reduction technique](#), *Atmospheric Chemistry and Physics*, 18, 2, 735-756, 10.5194/acp-18-735-2018
- Montzka, Stephen A., Geoff S. Dutton, Pengfei Yu, Eric Ray, Robert W. Portmann, John S. Daniel, Lambert Kuijpers, Brad D. Hall, Debra Mondeel, Carolina Siso, J. David Nance, Matt Rigby, Alistair J. Manning, Lei Hu, Fred Moore, Ben R. Miller and James W. Elkins, (2018), [An unexpected and persistent increase in global emissions of ozone-depleting CFC-11](#), *Nature*, 557, 7705, 413-417, 10.1038/s41586-018-0106-2
- Hall, B.D., S.A. Montzka, G. Dutton and J.W. Elkins, (2018), [Ozone Depleting Gases \[in "State of the Climate in 2017"\]](#), *Bulletin of the American Meteorological Society*, 99, 8, S49-S49, 10.1175/2018BAMSStateoftheClimate.
- Dlugokencky, E. J., B.D. Hall, S.A. Montzka, G. Dutton, J. Muhle and J.W. Elkins, (2018), [Long-lived greenhouse gases \[in "State of the Climate in 2017"\]](#), *Bulletin of the American Meteorological Society*, 99, 8, S46-S48, 10.1175/2018BAMSStateoftheClimate.
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Membership:

American Geophysical Union

Eric A. Ray

Education

Ph.D. Atmospheric Sciences, University of Washington, June 1997.

M.S. Atmospheric Sciences, University of Washington, August 1993.

B.A. Physics and Astrophysics, University of California at Berkeley, May 1990.

Experience

Research Scientist III, Cooperative Institute for Research in Environmental Sciences, University of Colorado, NOAA/CSD, October 2008-present.

Research Scientist II, Cooperative Institute for Research in Environmental Sciences, University of Colorado, NOAA/AL, November 2000-September 2008; NOAA/CMDL, April-November 2000.

Research Scientist I, Cooperative Institute for Research in Environmental Sciences, University of Colorado, NOAA/CMDL, August 1998-April 2000.

National Research Council Research Associate, NOAA Group, NOAA/CMDL, July 1997-July 1998. Advisor: Dr. James W. Elkins.

Graduate Research Assistant, Department of Atmospheric Sciences, University of Washington, July 1990-May 1997. Advisor: Prof. James R. Holton.

Selected Awards

CIRES Science and Engineering Outstanding Performance Award in 2019

2 CIRES Bronze Awards in 2007 and 2013

9 NASA Group Achievement Awards (1997-2018)

Selected Publications (h-Index: 23)

Ray, E. A., R. W. Portmann, P. Yu, J. Daniel, S. A. Montzka, G. S. Dutton, B. D. Hall, F. L. Moore and K. H. Rosenlof, The stratospheric quasi-biennial oscillation influence on trace gases at the Earth's surface, *Nature Geosci.*, accepted, 2019.

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