## Nomination Statement

It is my great pleasure to nominate Dr. Brian McDonald for a CIRES Outstanding Performance Award. Brian deserves this award for building novel scientific tools, carrying out creative analyses of CIRES and NOAA data, and interacting with his colleagues to develop unexpected perspectives that are changing how scientists and the public think about human activities and air quality.

Brian received a Master's degree in Public Policy and Master's and PhD degrees in Civil and Environmental Engineering from the University of California, Berkeley. He joined CIRES in 2014 as a Visiting Postdoctoral Fellow and is now a CIRES Research Scientist I. Brian is also affiliated with the Chemical Sciences Division of NOAA's Earth System Research Laboratory.

Brian is a scientific innovator in the development of anthropogenic emissions inventories -- catalogs of the amounts of chemicals released into the atmosphere by human activities. Brian's elegant approach to this complex problem allows him to consistently quantify and understand the sources of chemical precursors of ozone and particulate matter, pollutants that are regulated because of their impacts on human health and agriculture. Brian is significantly advancing the development and evaluation of emissions inventories, work that serves the needs of scientists, regulators, industries, and the community at large. His contributions to improving emissions science, described in more detail in this application, provide the solid scientific foundation that is critically needed by those who must adhere to or set health-based air pollution regulations. Good decisions come from accurate information, and Brian's research is improving emissions inventories and informing better decisions.

Beyond his scientific achievements, Brian's skills as a communicator, bridge-builder, and teacher are key to making his research relevant to

those who benefit from his work. Not satisfied to only publish his work in scientific journals, Brian puts forth the extra effort to synthesize his findings for colleagues at regulatory agencies and to help those agencies to improve their own inventories. Brian's unique perspective as a scientist, engineer, and public policy expert have enabled him to translate his scientific findings into information that can be readily used by those responsible for making decisions about our environment. Brian is also deeply committed to mentoring the next generation of scientists, providing young scientists with real-world experience by including them as collaborators in his research.

Brian McDonald is an exemplary early-career CIRES Research Scientist who is skilled and competent beyond his years. He is quite literally changing the way that we think about air pollution. He deserves to be recognized for his extraordinarily innovative research into pollution emission sources; his creative approaches to solving difficult scientific problems; his collaborative efforts to translate his science into information that benefits CIRES's and NOAA's stakeholders; and his dedication to training early-career scientists. The CIRES Outstanding Performance Award would be a fitting recognition of Brian's extraordinary achievements.

## Criteria

***Criteria 1: Development of new scientific, engineering and/or software tools or models directly resulting in novel research valuable to CIRES and the wider scientific community.***

Brian McDonald's cutting-edge research has produced new emissions tools that are proving to be invaluable to scientists at CIRES, NOAA and beyond, while also changing the way policymakers think about air pollution.

Emissions inventories, generally prepared by national or state regulatory agencies, aim to account for the amount of pollutants emitted to the

atmosphere. Inventories provide a quantitative link between human behavior and atmospheric impacts, and so they are fundamental inputs to chemical-transport models used by scientists, regulatory agencies, and health experts to understand the atmosphere, predict future changes in response to emission controls, and quantify human exposure to pollution. Current emissions reporting procedures and inventories used by regulators often fail to adequately capture real-world emissions, leading to poor model performance and hindering effective decision making. Brian's innovative, science-based inventory approaches combine high-quality ambient observations with publicly available source activity data to address shortcomings in the emissions reporting from three broad sectors: motor vehicles, fossil fuel production, and consumer products.

While it has long been recognized that motor vehicles play a key role in urban air pollution, there is tremendous complexity in representing emissions from millions of urban fossil-fueled vehicles. Brian has created an inventory that relies on real-world observations of motor vehicle emission factors and publicly available fuel use data. This "fuel-based" approach is rooted in the relatively simple metric of emissions per unit of fuel burned, derived from direct observations of thousands of vehicles in cities across the United States. His approach contrasts with current regulatory "per-mile-driven" inventories, which are based on regulatory models of driving activity combined with laboratory tests of a limited number of vehicles operating under ideal conditions. Brian's fuel-based inventory allows him to precisely quantify U.S. motor vehicle emissions of precursors to ozone and particulates. His fuel-based inventory of these precursors, including nitrogen oxides (NOx), in turn improves models of ozone pollution formation over the Eastern United States. Previously, those models had failed to produce accurate air quality forecasts, because inventory inputs from the U.S. Environmental Protection Agency (EPA) had overestimated vehicular NOx emissions by as much as a factor of two.

Building on his motor vehicle research, Brian is using similarly innovative approaches to improve the understanding of emissions from the rapidly changing US oil and natural gas production sector. He has shown that regulatory inventories overestimated emissions of NOx from combustion sources such as drilling rigs and the compressors that transport natural gas from wells to processing. Brian has devised a new method to estimate these emissions using public records on fuel use and well production equipment and emission factors reported in the scientific literature. Compared with the EPA's national inventory, Brian's new dataset agrees much better with top-down emission estimates derived from NOAA field campaigns.

While these achievements are impressive in and of themselves, Brian's most significant research to date is his extensive re-evaluation of volatile organic compound (VOC) emissions from the use of consumer chemicals, including personal care products, cleaners, paints, adhesives, and pesticides. Brian has built a new emissions inventory that follows hundreds of VOC compounds from raw feedstocks through the chemical manufacturing process to the finished products used every day by U.S. consumers. While 15 times more petroleum is consumed as fuel than is used as ingredients in industrial and consumer products, Brian shows that VOC emissions from consumer products are roughly equal to those from fuel. Current air pollution inventories, like those produced by EPA, underestimate VOC emissions by consumer and industrial products by a factor of two or three, while at the same time overestimating the contribution from vehicular sources. With the help of many colleagues, including several CIRES scientists, Brian has demonstrated that recent indoor and outdoor measurements in Los Angeles can only be explained by combining his VOC emissions estimates for consumer product usage with those from fossil fuel combustion and other known sources.

***Criteria 2: Uncommon initiative, resourcefulness, and/or scientific creativity conducting research with potential to expand or change the direction of a particular field or discipline.***

Brian McDonald's work substantially contributes to CIRES and NOAA's success in improving atmospheric science, while providing new directions for the scientific and regulatory communities. His inventory tools are changing the way that scientists and regulators think about the emissions from key economic sectors. Brian's work provides key input to atmospheric researchers at CIRES, NOAA, and elsewhere who are trying to understand changes in air quality and climate. Scientists will now carry out new research studies to confirm Brian's findings and to better understand the atmospheric implications of his inventories. Ultimately, society will benefit from Brian's novel approaches, as state and national authorities charged with making environmental policy will use his work to improve their understanding of pollution sources.

For example, Brian's fuel-based approach for motor vehicle emissions is now being extensively compared to the US EPA's own motor vehicle emissions model in an effort to understand where the EPA model falls short. Brian's work also informs the motor vehicle inventory of the California Air Resources Board. His inventory was the key input to model simulations that successfully replicated NOAA field observations made during the past decade in Los Angeles and in the Southeastern United States. Brian's inventory explains how the implementation of pollution controls on cars and trucks across the nation led to 50 years of improvements in the pollutants that are key ingredients of U.S. urban smog, and his research and knowledge of motor vehicles were invaluable in understanding why air pollution in U.S. and European cities followed different paths. Because of contrasting strategies for emissions control-Europe focused on greenhouse gas emissions, while the United States focused on emissions relevant to air quality-NOx levels have trended down in Los Angeles but not in London or Paris.

Brian's work has had important implications for regulators seeking to minimize the environmental impact of oil and gas production operations. For example, he provided the improved understanding of NOx emissions needed to accurately model wintertime ozone levels in a Utah oil and

gas basin that frequently exceed levels considered safe. His inventory approaches may also improve emission estimates in fossil fuel basins located near cities, such as Denver, where summertime ozone levels increasingly violate standards. Brian's oil and gas inventories may ultimately help to inform air quality managers who are responsible for protecting the health of millions across the nation.

With his groundbreaking study of consumer products, Brian finds that these household chemicals now rival motor vehicles as a source of urban particulate matter. As a result, consumer products are now likely the dominant source of particulate matter exposure for urban Americans who spend most of their time indoors. Because even relatively low levels of particulate matter negatively impact human health, regulatory agencies have gradually tightened standards for outdoor particulate matter levels. Now Brian's research is helping scientists and others recognize the impacts of both indoor and outdoor air quality on human health. His study of consumer products is spurring numerous lines of research inquiry, as scientists make measurements of the pollutants he predicts, model their behavior as sources of particulates, and quantify their impacts on human health. A highly respected British scientist, Professor Alastair Lewis, wrote a perspective (see Supporting Documentation) on the importance of the Science paper by Brian and his colleagues that was published on 15 February 2018. Professor Lewis states that this work will "alter predictions of urban air quality and challenge the existing policy framework for emissions control." In other words, Brian is doing truly groundbreaking work that is changing the direction of atmospheric chemistry.

***Criteria 3: Participation in collaborative and/or multidisciplinary research that engages a broader cross-section than the nominee's typical scientific or engineering community.***

Brian McDonald is the consummate colleague who has built strong collaborations with many scientists at CIRES, NOAA, and premier research institutions across the United States and around the world.

Brian works closely with nearly every research program within NOAA's Chemical Sciences Division. He has cultivated strong partnerships with many senior researchers, including several CIRES and AGU Fellows. Brian's inventories and insights are in high demand by scientists modeling the atmosphere, analyzing ambient observations, planning field studies, and evaluating the newest satellite products. His research has resulted in 17 peer-reviewed publications since 2010, with several more manuscripts currently in preparation. This is an extraordinary level of productivity for a researcher who received his PhD just over 3 years ago. Brian's superb communication skills are highly valued by CIRES and NOAA and have resulted in invitations to speak to many scientific audiences, including the National Institute for Standards and Technology, the National Center for Atmospheric Research, NASA, the American Geophysical Union, the University of Colorado Boulder, and Colorado State University.

Brian's most important paper so far, examining the emissions and impacts of consumer products, was published this week in the leading US journal Science (see Supporting Documentation). As first author, Brian brought together 19 other scientists from 12 institutions, including several CIRES researchers, in a tour-de-force of inventory development, observational analysis, and air quality modeling. This paper was selected by the American Association for the Advancement of Science (AAAS), the publisher of Science, to be featured in a press briefing at the 2018 AAAS Annual Meeting in Austin, Texas, later this week. The Science paper has already generated tremendous media interest; Brian and his colleagues have been interviewed by the British Broadcasting Corporation, the New York Times, the Washington Post, the Atlantic magazine, National Public Radio, Science Friday, and other major press outlets.

In addition to communicating his work to scientific colleagues, Brian is also determined to make his findings useful for environmental regulators and policy experts. Even at this early stage of his career, Brian is one of

those rare scientists with the communication and diplomacy skills necessary to go beyond his research to provide objective information to those who formulate the nation's environmental regulations and decisions. By sharing his research, Brian facilitates the development of improved regulatory emission models and informs the design of pollution control strategies. One example of this outreach is an ongoing series of federal interagency discussions in which he is helping the U.S. EPA improve its vehicle emissions model, which is used by state air quality managers mandated to meet Clean Air Act standards. Brian also participates in the Global Emissions Initiative's expert group focused on improving the world's inventories of VOC emissions, which inform air pollution control efforts in developing regions and contribute to the scientific basis for international environmental assessments. Brian takes public service seriously: He served on the City of Berkeley's Community Environmental Advisory Commission, worked as a policy consultant to California's and San Francisco's public utilities commissions, and is now advising air quality decision-makers in Colorado.

Brian also contributes to science and to society by seeking out opportunities to engage and train young scientists who carry out original research and present their findings to others. As a graduate student, he mentored undergraduate Zoe McBride, who developed highly-resolved GIS maps of transportation emissions; they co-authored a journal article. At CIRES/NOAA, Brian mentored Alan Gorchov-Negron, a geophysics major at Brown University who earned both NCAR's SOARS and NOAA's Hollings scholarships. Mr. Gorchov-Negron presented his work at an American Geophysical Union conference, is writing a paper with Brian on their oil and gas emissions work, and is now in a PhD program in atmospheric science at the University of Michigan. Another NOAA Hollings undergraduate, Justin DuRant, worked with Brian to develop the national fuel-based motor vehicle emissions inventory, presented the work at an American Meteorological Society meeting, and is a co-author of a paper that was just submitted. Post-undergraduate intern Shelby Tisinai and Brian performed data analysis on global volatile organic

compound emission inventories; her results were presented at EPA's International Emissions Inventory Conference. Several of these students have gone on to graduate school in part because of the rewarding projects that they worked on with Brian.