# Environment and Natural Resources Trust Fund
# Research Addendum for Peer Review

*Project Manager Name:* Julian Marshall
*Project Manager Email Address:* julian@umn.edu
*Project Title:* Addressing Ozone Pollution in Minnesota: Equity and Efficiency
*Project Number:* 138-F1+2+5

## ABSTRACT

The state of Minnesota is in attainment with EPA's current ozone standard but is in danger of not meeting stricter standards proposed by EPA. This project combines satellite measurements, monitoring data, and air quality modeling to study ozone pollution and exposure in Minnesota, and examines the effectiveness and environmental equity of potential control options. Our work will develop a better understanding of the chemistry impacting ozone concentrations in Minnesota, thereby informing the design of effective control strategies.

## 1. INTRODUCTION

Ozone exposure increases susceptibility to respiratory infections, medication use by asthmatics, and hospital admissions for individuals with respiratory disease [*Halonene et al*., 2010]. Ozone may contribute to premature death, especially in people with heart and lung disease [*Jerrett et al.,* 2009; *Bell et al.*, 2006]. Ozone also reduces crop yields and harms sensitive ecosystems [*VanDingenen et al.,* 2009]. Ground-level ozone is one of the six criteria pollutants defined in the federal Clean Air Act. For all criteria pollutants, the Environmental Protection Agency establishes health-based concentration standards, known as National Ambient Air Quality Standards (NAAQS). States must measure ambient (outdoor) concentrations to ensure compliance with those standards.

Minnesota is in attainment with the current ozone standard (75 ppb, 8-hour average) but could well violate stricter standards (60-70 ppb) currently being proposed by the Environmental Protection Agency [*EPA*, 2010]. Figure 1 shows policy-relevant ozone concentrations (fourth highest 8-hour average in 2009) for several monitoring sites maintained by the Minnesota

Pollution Control Agency (MPCA). Several monitors reported concentrations in the range proposed by EPA for the future NAAQS (60-70 ppb).

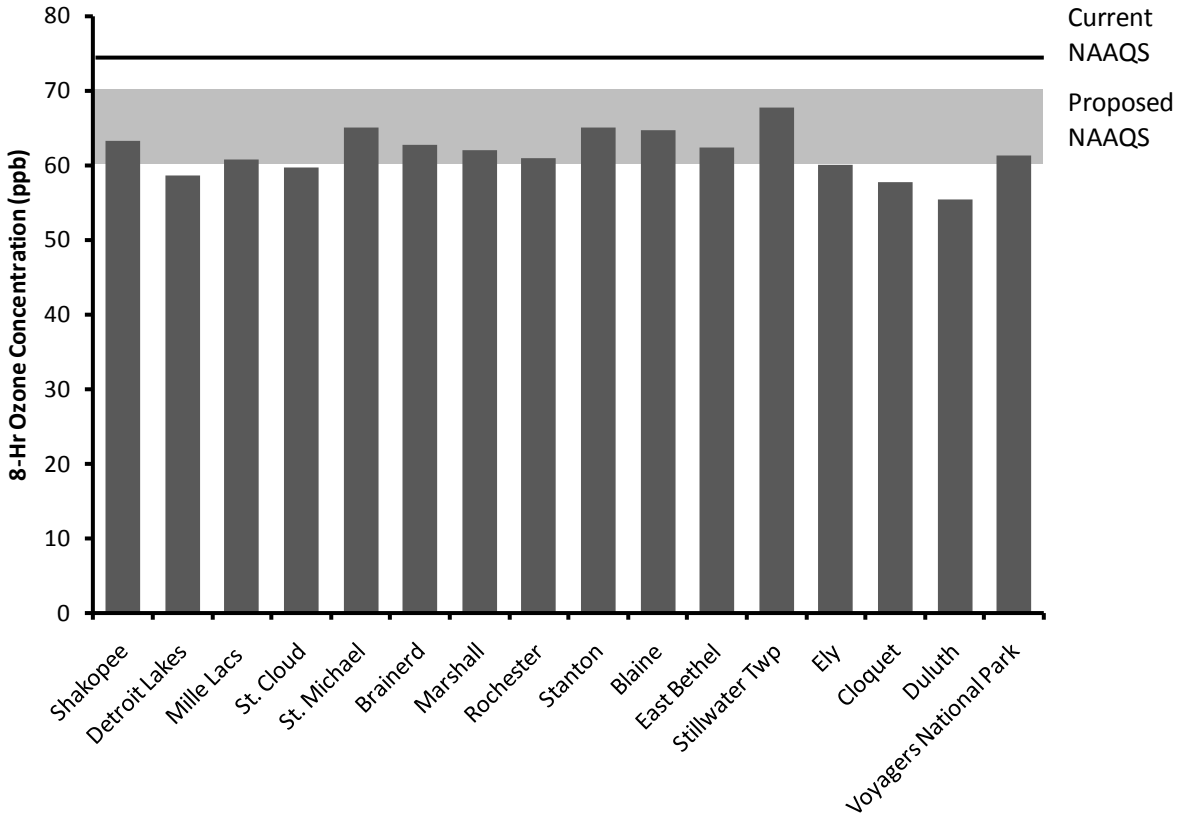


**Figure 1 - The 4th highest 8-hour ozone concentrations for MPCA monitor sites throughout the state of Minnesota in the year 2009.**

Reducing ambient ozone concentrations is a complicated process for several reasons. Ground-level ozone is not emitted directly, but instead is formed in the atmosphere via a series of chemical reactions involving precursor nitrogen oxides ($NO_x$) and volatile organic compounds (VOCs). The chemical reactions that generate ozone are complex and interdependent; lowering emissions of a precursor will not necessarily yield an improvement in ozone concentrations. The ozone impacts of a given control strategy depend strongly on the relative abundance of the two precursors ($NO_x$; VOCs), as well as local conditions (e.g., temperature, meteorology, spatial and temporal distribution of emissions). In some cases, poorly-chosen emission reductions can actually worsen ozone pollution.

Existing research shows that in areas with an abundance of VOCs ("$NO_x$-limited regimes"), reducing $NO_x$ improves ozone but reducing VOCs has little impact. In areas with an abundance

of $NO_x$ ("VOC-limited regimes"), reducing VOCs improves ozone but reducing NOx can actually increase ozone concentrations, including the peak ozone concentrations regulated by the EPA. Developing a robust understanding of which of these regimes are present in Minnesota, and where, will improve our understanding of how ozone concentrations will respond to various policy-driven changes in precursor emissions.

Designing and testing effective control strategies for Minnesota to meet the new federal standard will require a strong understanding of

1) the current state of regional ozone chemistry,
2) relative importance of anthropogenic (man-made) and biogenic (plant-based) precursor emissions in the state and region,
3) the extent to which that pollution from neighboring states affects air quality in Minnesota, and
4) the populations that are impacted by the ozone concentrations.

Knowing which socioeconomic populations are most impacted by exposure to ozone, and how those distributions would shift under specific emission control options, is a critical aspect of pollution control strategy. This project will combine regional air quality modeling, satellite measurements, and MPCA monitoring data to study the current state of ozone pollution and precursor emissions in Minnesota, and examine the effectiveness and environmental equality of a range of potential control scenarios.

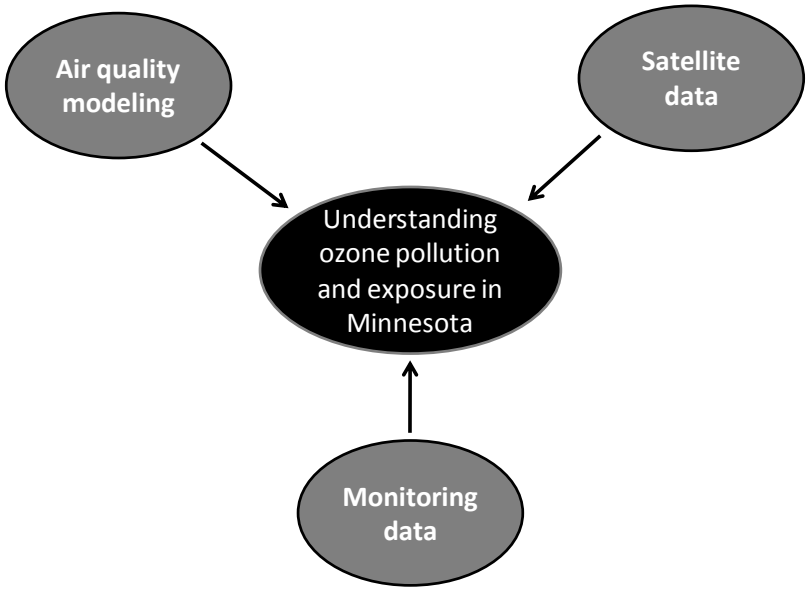


**Figure 2 – Information employed in this study.**

Our research complements MPCA's work in this area. Specifically, if Minnesota violates the stricter ozone standard, MPCA would be required to model potential control strategies; our project extends beyond MPCA's purview by evaluating satellite data to understand the chemistry of ozone formation in Minnesota, and investigating equity and environmental justice aspects of current ozone exposure and of potential control scenarios.

# 2. HYPOTHESIS AND GOALS

We will apply satellite measurements, ground-based observations, and an air quality model to answer the following questions related to ozone in Minnesota:

- Where are the high ozone concentrations ("hot spots") in Minnesota?
- Where are the $NO_x$-limited and VOC-limited regimes throughout the state?
- How do ozone concentrations change under different control strategies?
- What impact do emissions from outside Minnesota have on ozone concentrations in Minnesota?
- What specific populations are most severely impacted by high ozone concentrations?

# 3. METHODOLOGY

## 3.1 Description of Model and Data Sources

### *3.1.1 Air Quality Model*

For this study, we will use a state-of-the-science three-dimensional regional chemical transport model, CAMx [*ENVIRON*, 2010]. CAMx is approved by EPA for use in policy development and is commonly used for ozone modeling. We will employ a coarse (12 km) grid for the Midwest, and a fine (4-km) nested grid for Minnesota. We will model April–October (for 2009) as this "ozone season" is the relevant time period for high ozone concentration days. We will model chemical reaction rates using a standard approach, the Carbon Bond Mechanism Version 5 which is based on the original Carbon Bond mechanism developed by *Gery et al.* [1989]. This approach represents the chemistry of ozone formation by grouping organic species according to functional groups.

CAMx requires a variety of inputs related to meteorology and emissions. Meteorological inputs include temperature, pressure, wind speeds, and cloud information, and these will be

developed using the Weather Research and Forecasting (WRF) model [*NCAR*, 2010]. The emissions inputs will be developed using the Sparse Matrix Operator Kernel Emissions (SMOKE) System [*UNC*, 2009]. SMOKE uses EPA's National Emission Inventory as inputs, and processes them for ingestion by CAMx.

This work will also apply the Decoupled Direct Method (DDM) in CAMx in order to evaluate the sensitivities of ozone concentrations to different source regions. The DDM tool tracks sensitivities through the different modeled processes [*Dunker et al*., 2002], and will provide key information for determining the impact on Minnesota ozone from emissions transported across state lines.

*3.1.2 Ground-Based Data*

We will obtain ozone concentrations measured by MPCA at their monitoring sites, which are located throughout the state (from MPCA's Environmental Access Database, www.pca.state.mn.us). The MPCA sites record hourly ozone information from late spring until early fall, and span urban, suburban and rural areas. Our investigation will use the MPCA monitoring data to evaluate CAMx model results and to quantify model accuracy.

*3.1.3 Satellite Data*

We will use satellite data to analyze $NO_x$ and VOC concentrations across the state, and to further evaluate the CAMx output. The MPCA data provide good temporal coverage, but only in certain locations where the monitors are located. The satellite measurements will be a critical addition to this by providing uniform data coverage across the state (though with less temporal information). We will use formaldehyde (HCHO) and nitrogen dioxide ($NO_2$) as indices for VOCs and $NO_x$, respectively, in terms of testing the CAMx model and its emission inventories.

For this work, we will employ measurements of HCHO and $NO_2$ columns from the Ozone Monitoring Instrument (OMI) [*Millet et al.,* 2008; *Duncan et al.,* 2009]. Of the available satellite sensors, OMI's high spatial resolution (13×24 $km^2$ at nadir) and daily global coverage offer substantial advantages for resolving spatial variability and reducing measurement uncertainty through improved sampling statistics. The small footprint also reduces data contamination by clouds, which is the primary source of error in the retrievals [*Millet et al.,* 2006].

## 3.2 Specific Tasks

### *3.2.1 Characterization of Current Ozone Levels*

Using model predictions, as informed by the ground- and satellite-based observations, we will evaluate areas throughout the state based on the degree to which regional ozone production is $NO_x$- versus VOC-limited. We will apply a sensitivity analysis in CAMx (perturbing $NO_x$ slightly and examining the resulting incremental change in ozone production) to do this classification. As mentioned earlier, this regime identification is critical for developing potential control strategies. We will also use this information to determine areas of particular concern (ozone "hot spots") across the state. This will allow us to focus the development of potential strategies with those areas in mind.

This analysis represents fundamental information for effective ozone control, since controlling the wrong precursor pollutant can be ineffective in reducing ozone, and may even make things worse in some areas. This task will provide valuable information for designing and testing ozone pollution control strategies most likely to be effective in Minnesota.

### *3.2.2 Evaluation of Potential Control Strategies*

We will evaluate categories of potential emission control strategies to determine the effectiveness of each in reducing ozone pollution. For example, we will start by studying the effectiveness of statewide controls on emissions from certain sectors (e.g. light- or heavy-duty vehicle emissions, electric power plants, or light industry). We will carry out this portion of the investigation using sensitivity analysis: by decreasing the emissions from these sectors in the emissions inventory in CAMx, and then observing the resulting change in modeled concentrations. We will then test region-specific controls (e.g. urban vs. rural) to account for differing ozone chemistry regimes in different regions of the state. We can then compare the predicted ozone concentrations and potential ozone exceedances for each of the scenarios, including the base case (no emission reductions) scenario. From these results we can determine which sectors provide the most promising options for decreasing ozone concentrations throughout the state.

As a next step, we will identify the impact of emissions from outside the state of Minnesota on air quality in the state of Minnesota. We will do this by studying the sensitivity of the ozone concentrations using the DDM tool in CAMx (described above). Since ozone production is non-linear, studying these sensitivities will help to quantify the level of improvement in ozone pollution that is achievable by Minnesota action alone, while also allowing us to study the potential impacts of Minnesota emissions on other areas in the Upper Midwest.

The exposure impacts of a potential control strategy may vary among demographic groups. The investigations outlined above will evaluate not only ground-level ozone concentrations but also ozone exposures to specific socioeconomic groups. Specifically, for each potential control strategy we will explore the extent to which ozone exposures would increase or decrease for specific socioeconomic or demographic groups. Air quality legislation aims not only to safeguard public health but also to do so equitably across the population; our results will help inform how to accomplish this.

The work proposed here represents a state-of-the-science investigation of ozone chemistry. The modeling effort is computationally intensive. We will use computing resources at the Minnesota Supercomputing Institute at the University of Minnesota which will allow us to run the air quality model in parallel over hundreds of processors. Employing MSI resources will be necessary for us to test several control strategies and accomplish the overall goals of the project.

## 4. RESULTS, DELIVERABLES AND THE TIMETABLE

Two-year project, 8/1/2011 – 7/31/2013.

| Results | Deliverable | Completion Dates |
|---|---|---|
| **1a.** Model ozone concentrations using CAMx. Evaluate CAMx output by comparing against MPCA measurements and against satellite observations of nitrogen dioxide and formaldehyde. | Hourly, spatially resolved ozone, nitrogen dioxide and VOC concentrations from CAMx that have been compared to ground- and satellite-based observations. | 4/30/2012 |
| **1b.** Identify hotspot locations for ozone pollution and the specific populations that are impacted. | Map of ozone hot spots in Minnesota. | 4/30/2012 |
| **1c.** Use satellite measurements and model results to diagnose the sensitivity of ozone pollution in Minnesota to $NO_x$ versus VOC emission control strategies. | Map showing $NO_x$ and VOC-sensitivity for ozone production across Minnesota. | 6/30/2012 |
| **2a.** Compare the effectiveness of statewide controls on emissions. | Comparison of predicted ozone exceedances and concentrations associated with each control scenario. | 9/30/2012 |

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|---|---|---|
| **2b.** Determine the effectiveness of region-specific controls. | Comparison of predicted ozone exceedances and concentrations associated with each control scenario. | 11/30/2012 |
| **2c.** Evaluate the impact of out-of-state emissions on ozone in Minnesota. | Sensitivities of ozone in Minnesota to emissions from outside Minnesota. | 2/28/2013 |
| **2d.** Compare the inequity of ozone exposure under each control strategy. | Exposures for different groups currently and under each control scenario. | 5/30/2013 |

## 5. DISSEMINATION AND USE

The findings from this research will be shared with the Minnesota Pollution Control Agency to aid in their planning. They will also be shared with the scientific community through publication in highly ranked peer-reviewed journals.

## 6. BUDGET

**Total Trust Fund Request Budget (*2 years*)**

| **Budget Item** | **Amount** |
|---|---|
| **Personnel:** | |
| Professor Julian Marshall, PI *(0.9 month summer salary per year for two years, $35,140 salary, $11,702 fringe, 33.3% fringe rate)* | $ 46,842 |
| Professor Dylan Millet, Co-PI (0.9 month summer salary per year for two years, $16,879 salary, $5,621 fringe, 33.3% fringe rate) | $ 22,500 |
| Dr. Kristina Wagstrom, Co-PI (full support for two years, $88,000 salary, $17,494 fringe, 19.9% fringe rate) | $ 105,494 |
| Graduate Research Assistant, Master's Student (full support for two years, $43,410 salary, $31,754 fringe - includes health care and tuition) | $ 75,164 |
| **TOTAL ENVIRONMENT & NATURAL RESOURCES TRUST FUND $ REQUEST** | $ 250,000 |

**Other Funds**

| Source of Other Funds | Amount |
|---|---|
| **Other Non-State $ Being Applied to Project During Project Period:** | |
| Computational expenses at the Minnesota Supercomputing Institute (MSI does not charge us for the use of the resources, this amount is the estimated value of the use of the resources) | $ 15,000 |

## 7. CREDENTIALS

Abbreviated C.V.'s are attached for each of the investigators listed below on the project.

**Dr. Julian Marshall,** Assistant Professor, Department of Civil Engineering, University of Minnesota

B.S., 1996, Chemical Engineering, *Princeton University*
M.S., 2002, Energy and Resources, *University of California - Berkeley*
Ph.D., 2005, Energy and Resources, *University of California - Berkeley*

Dr. Julian Marshall will be the overall coordinator of this project. His research focuses on exposure to air pollution, including pollution dispersion modeling and environmental justice aspects of air quality management.

**Dr. Dylan Millet,** Assistant Professor, Department of Soil, Water and Climate, University of Minnesota

B.S., 1998, Chemistry, *University of British Columbia*
Ph.D., 2003, Ecosystem Science, *University of California - Berkeley*

Dr. Dylan Millet's research applies measurements and models to understand the impacts of human activity and natural processes on the chemical composition of the atmosphere. His current research combines ground- and satellite-based measurements to better understand air quality and atmospheric composition.

**Dr. Kristina Wagstrom,** Postdoctoral Associate, Department of Civil Engineering, University of Minnesota

B.S., 2004, Chemical Engineering, *Illinois Institute of Technology*
Ph.D., 2009, Chemical Engineering, *Carnegie Mellon University*

Dr. Kristina Wagstrom's research applies regional air quality modeling (using CAMx) and source apportionment approaches to study the origins, transport, and fate of air pollutants.

# 8. REFERENCES

Bell ML, RD Peng, F Dominici, (2006), The exposure-response curve for ozone and risk of mortality and the adequacy of current ozone regulations, *Environmental Health Perspectives* 114(4), 532-536.

Duncan, B. N., Y. Yoshida, J. R. Olson, S. Sillman, R. V. Martin, L. Lamsal, Y. Hu, K. E. Pickering, C. Retscher, D. J. Allen, J. H. Crawford (2010), Application of OMI observations to a space-based indicator of NOX and VOC controls on surface ozone formation, *Atmos. Environ., 44*(18), 2213-2223.

Dunker, A.M., G. Yarwood, J.P. Ortmann, G.M. Wilson (2002), Comparison of Source Apportionment and Source Sensitivity of Ozone in a Three-Dimensional Air Quality Model, *Env. Sci. Technol*., *36*, 2953-2964.

EPA (2010) National ambient Air Quality Standards for Ozone, *Federal Register*, 75(11), 2938-3052.

ENVIRON International Corporation (2010), *CAMx User's Guide – Version 5.20*. Available from: www.camx.com.

Gery, M. W., G.Z. Whitten, J.P. Killus, M.C. Dodge (1989), A Photochemical Kinetics Mechanism for Urban and Regional Scale Computer Modeling, *Journal of Geophysical Research-Atmospheres,* 94(D10), 12925-12956.

Halonen, J.I., T. Lanki, P. Tiittanen, J.V. Niemi, M. Loh, J. Pekkanen (2010), Ozone and case-specific cardiorespiratory morbidity and mortality, *J. of Epidem. And Comm. Health*, 64(9), 814-820.

Jerrett, M., R.T. Burnett, C.A. Pope III, K. Ito, G. Thurston, D. Krewski, Y. Shi, E. Calle, M. Thun (2009), Long-Term Ozone Exposure and Mortality, *The New England Journal of Medicine*, 360(11), 1085-1095.

Millet, D. B., D. J. Jacob, S. Turquety, R. C. Hudman, S. Wu, A. Fried, J. Walega, B. G. Heikes, D. R. Blake, H. B. Singh, B. E. Anderson, A. D. Clarke (2006), Formaldehyde distribution over North America: Implications for satellite retrievals of formaldehyde columns and isoprene emission, *J. Geophys. Res., 111*, D24S02.

Millet, D. B., D. J. Jacob, K. F. Boersma, T. Fu, T. P. Kurosu, K. V. Chance, C. L. Heald, A. Guenther (2008), Spatial distribution of isoprene emissions from North America derived from

formaldehyde column measurements by the OMI satellite sensor, *J. Geophys. Res., 113*, D02307.

NCAR - National Center for Atmospheric Research (2010), *Weather Research and Forecasting Model ARW Version 3 Modeling System Users Guide*. Available from: www.wrf-model.org.

UNC - Institute for the Environment at The University of North Carolina at Chapel Hill (2009), *SMOKE v2.6 User's Manual*. Available from: www.smoke-model.org.

Van Dingenen, R., F.J. Dentener, F. Raes, M.C. Krol, L. Emberson, J. Cofala (2009), The global impact of ozone on agricultural crop yields under current and future air quality legislation, *Atmos. Env*., *43*(3), 604-618.

# JULIAN D. MARSHALL

**Education/training**

| Institution | Degree | Year(s) | Field of study |
|---|---|---|---|
| Princeton University | B.S.E. with high honors | 1996 | Chemical Engineering |
| University of California Berkeley | M.S. | 2002 | Energy and Resources |
| University of California Berkeley | Ph.D. | 2005 | Energy and Resources |
| University of British Columbia (UBC) | Postdoctoral training | 2005-6 | Environmental Health |

**Present position**: **Assistant Professor of Environmental Engineering** (since January 2007) and **McKnight Land-Grant Professor** (since July 2009), **Department of Civil Engineering, University of Minnesota** (UMN). Affiliated faculty in Mechanical Engineering, Urban and Regional Planning, and Environmental Health Sciences, UMN; and School of Environmental Health, UBC. Member, Minnesota Population Center. Faculty Scholar, Center for Transportation Studies, UMN. Resident Fellow, Institute on the Environment, UMN.

**Previous positions**

- Independent Contract Researcher, Berkeley, CA, 2000–2005. Conducted research on energy and the environment for the California Air Resources Board (Sacramento, CA), Environmental Defense (Oakland, CA), United Nations University (Tokyo, Japan), and the U.S. Agency for International Development (Jakarta, Indonesia)
- Student Researcher, Lawrence Berkeley National Lab, Berkeley, CA, 2001–2005
- Volunteer, Ladakh Ecological Development Group, Kashmir, India, 1999
- Lecturer and International Fellow, Temasek Polytechnic, Singapore, 1998–1999
- Environmental Consultant, Environ Corporation, Emeryville, CA, 1996–1997

**Teaching**

CE3501 Introduction to Environmental Engineering (F2007, S2008)
CE5180-003 Air Quality Engineering (F2008, F2009)
CE5180-001 Design for Sustainable Development (S2009, S2010)
CE8490 Technologies for Sustainable Societies (S2007, F2007)

**Research**

I am interested in energy and environmental impacts of cities, especially urban transportation systems. My group analyzes data and builds models to understand the air pollution, climate-change emissions, and health impacts of the built environment. The goal is to investigate approaches to improve the environmental and public health aspects of urban areas. My three areas of focus are air pollution and health; climate-change emissions from transportation; and environmental and health impacts of urban form.

**Invited presentations**

- Presented to Minnesota State Legislature (3/2008) on reducing climate-change emissions. Twice presented to California Air Resources Board (5/2002, 1/2006)
- Twenty invited presentations, including to international conferences in Brazil, Canada, Colombia, France, Japan, Spain, and Thailand. Topics include air quality engineering and reducing climate-change emissions

**Honors and fellowships**

- Graduate Research Fellowship, National Science Foundation (NSF), 2000–2003
- Fellowship, U.C. Toxic Substances Research & Teaching Program, 2003–2005
- Dissertation Fellowship, U.C. Transportation Center, 2003–2004
- Outstanding Graduate Student Instructor Award, U.C. Berkeley, 2005. Award states: "Each year, fewer than 10% of GSIs earn this distinguished award"
- Post-doctoral research fellowships from the School of Environmental Health and from the Bridge Program in engineering, policy, and health, UBC, 2005–2006

**Selected publications (out of 22 articles published and 4 currently in review)**

JD Marshall, "Environmental equality: air pollution exposures in California's South Coast Air Basin," Atmospheric Environment, 42(21), 5499-5503, 2008.

JD Marshall, E Nethery, M Brauer, "Within-urban variability in ambient air pollution: comparison of estimation methods," Atmospheric Environment, 42(6), 1359-1369, 2008. *Listed as a "most-downloaded" article.*

PJ Marcotullio, JD Marshall, "Potential futures for road transportation $CO_2$ emissions in the Asia Pacific," Asia Pacific Viewpoint, 48(3), 355–377, 2007.

JD Marshall, PW Granvold, AS Hoats, TE McKone, E Deakin, WW Nazaroff, "Inhalation intake of ambient air pollution in California's South Coast Air Basin," Atmospheric Environment, 40(23), 4381–4392, 2006.

JD Marshall, E Behrentz, "Vehicle self-pollution intake fraction: children's exposure to school bus emissions," Environmental Science & Technology, 39(8), 2559-2563, 2005. *Widely reported in media, including* The New York Times *and* L.A. Times.

JD Marshall, TE McKone, EA Deakin, WW Nazaroff, "Inhalation of motor vehicle emissions: effects of urban population and land area," Atmospheric Environment, 39(2), 283-295, 2005. *Listed as a "most-downloaded article."*

JD Marshall, MW Toffel, "Framing the elusive concept of sustainability: a sustainability hierarchy," Environmental Science & Technology, 39(3), 673-682, 2005. *Listed as a "most-downloaded article."*

PJ Marcotullio, E Williams, JD Marshall, "Faster, sooner, and more simultaneously: how recent road and air transportation $CO_2$ emission trends in developing countries differ from historic trends in the United States," Journal of Environment and Development, 14(1), 125-148, 2005.

JD Marshall, WJ Riley, TE McKone, WW Nazaroff, "Intake fraction of primary pollutants: motor vehicle emissions in the South Coast Air Basin," Atmospheric Environment, 37(24), 3455–3468, 2003.

**Selected university service**

Director, Peace Corps Master's International Program, Department of Civil Engineering, UMN
Co-Director, Acara Challenge, Institute on the Environment, UMN
Chair, Civil Engineering undergraduate scholarship committee
Faculty Advisor, Engineers Without Borders

**Thesis advisor and postgraduate-scholar sponsor**

Current graduate students [7]: N Boeke, C Buckley, L Clark, S Hankey, K Lundquist, L Price, C Tessum
Current post-doctoral researchers [2]: E Novotny, K Wagstrom
Past graduate students [2]: A Both, R Wilson

# DYLAN B. MILLET

ASSISTANT PROFESSOR
UNIVERSITY OF MINNESOTA, DEPT OF SOIL, WATER & CLIMATE

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## • EDUCATION •

Ph.D. **University of California, Berkeley,** *ESPM - Ecosystem Sciences* (12/2003)
B.Sc. **University of British Columbia,** *Honours Chemistry* (05/1997)

## • APPOINTMENTS •

| | | |
|---|---|---|
| 2008-present: | **University of Minnesota:** | Assistant Professor |
| 2005-2007: | **Harvard University:** | Postdoctoral Fellow |
| 2004: | **U.C. Berkeley:** | Postdoctoral Fellow |

## • SELECTED AWARDS AND HONORS •

McKnight Land-Grant Professorship (2010-2012); NOAA Postdoctoral Fellowship in Climate and Global Change (2005-2007); Reginald A. Daly Postdoctoral Fellowship, Harvard University (2005-2007); National Research Council Postdoctoral Fellowship (2004, declined); DOE Graduate Research Environmental Fellowship (1999-2003); NASA Graduate Student Fellowship in Earth System Science (1999, declined); EPA Science to Achieve Results Graduate Fellowship (1999, declined); NSERC Postgraduate Scholarship (1998, declined); Society of Chemical Industry Merit Prize (top student in Honours Chemistry graduating class, 1997); U.B.C. Scholarship (1995/96-1996/97); U.B.C. Dean's Honour List (1992/93-1996-97); Agnes and Gilbert Hooley Scholarship in Chemistry (1995/96); J. Fred Muir Memorial Scholarship in Science (1995/96); Science Scholar (top twenty students in U.B.C. Faculty of Science, 1994/95-1995-96).

## • RESEARCH INTERESTS •

Atmospheric chemistry and biogeochemistry. Atmospheric sources and chemistry of reactive organics. Land-atmosphere interactions. Biogenic and anthropogenic influences on atmospheric composition and climate.

## • PUBLICATIONS • *(full list and reprints available at http://www.atmoschem.umn.edu)*

FIVE MOST CLOSELY RELATED TO PROPOSAL


Boeke, N.L., J.D. Marshall, S. Alvarez, K.V. Chance, A. Fried, T.P. Kurosu, B. Rappenglück, D. Richter, J. Walega, P. Weibring, and **D.B. Millet** (2010), Formaldehyde columns from the Ozone Monitoring Instrument: Urban versus background levels and evaluation using aircraft data and a global model, *J. Geophys. Res.*, submitted.

**Millet, D.B.**, D.J. Jacob, S. Turquety, R.C. Hudman, S. Wu, A. Fried, J. Walega, B.G. Heikes, D.R. Blake, H.B. Singh, B.E. Anderson, and A.D. Clarke (2006), Formaldehyde distribution over North America: Implications for satellite retrievals of formaldehyde columns and isoprene emission, *J. Geophys. Res.*, 111, D24S02, doi:10.1029/2005JD006853.

**Millet, D.B.**, D.J. Jacob, K.F. Boersma, T.M. Fu, T.P. Kurosu, K. Chance, C.L. Heald, and A. Guenther (2008), Spatial distribution of isoprene emissions from North America derived from formaldehyde column measurements by the OMI satellite sensor, *J. Geophys. Res.*, *113*, D02307, doi:10.1029/2007JD008950.

Parrish, D.D., **D.B. Millet**, and A.H. Goldstein (2009), Increasing ozone concentrations in marine boundary layer air inflow at the west coasts of North America and Europe, *Atmos. Chem. Phys.*, 9, 1303-1323.

**Millet, D.B.**, A.H. Goldstein, R. Holzinger, B.J. Williams, J.D. Allan, J.L. Jimenez, D.R. Worsnop, J.M. Roberts, A.B. White, R.C. Hudman, I.T. Bertschi, and A. Stohl (2006), Chemical characteristics of North American surface layer outflow: Insights from Chebogue Point, Nova Scotia, *J. Geophys. Res.*, *111*, D23S53, doi:10.1029/2006JD007287.

FIVE OTHER SIGNIFICANT PUBLICATIONS

**Millet, D.B.**, A. Guenther, D.A. Siegel, N.B. Nelson, H.B. Singh, J.A. de Gouw, C. Warneke, J. Williams, G. Eerdekens, V. Sinha, T. Karl, F. Flocke, E. Apel, D.D. Riemer, P.I. Palmer, and M. Barkley (2010), Global atmospheric budget of acetaldehyde: 3D model analysis and constraints from in-situ and satellite observations, *Atmos. Chem. Phys.*, 10, 3405-3425.

**Millet, D.B.**, E.L. Atlas, D.R. Blake, N.J. Blake, G.S. Diskin, J.S. Holloway, S. Meinardi, T.B. Ryerson, and G.W. Sachse (2009), Halocarbon emissions from the United States and Mexico and their global warming potential, *Environ. Sci. Technol.*, 43, 1055-1060.

Hudman, R.C., L.T. Murray, D.J. Jacob, **D.B. Millet**, S. Turquety, S. Wu, D.R. Blake, A.H. Goldstein, J. Holloway, and G.W. Sachse (2008), Biogenic vs. anthropogenic sources of CO over the United States, *Geophys. Res. Lett.*, *35*, L04801, doi:10.1029/2007GL032393.

**Millet, D.B.**, N.M. Donahue, S.N. Pandis, A. Polidori, C.O. Stanier, B.J. Turpin, and A.H. Goldstein (2005), Atmospheric volatile organic compound measurements during the Pittsburgh Air Quality Study: Results, interpretation and quantification of primary and secondary contributions, *J. Geophys. Res.*, *110*, D07S07, doi:10.1029/2004JD004601.

Hudman, R.C., L.T. Murray, D.J. Jacob, S. Turquety, S. Wu, **D.B. Millet**, M. Avery, A.H. Goldstein, and J. Holloway (2009), North American influence on tropospheric ozone and the effects of recent emission reductions: Constraints from ICARTT observations, *J. Geophys. Res.*, 114, D07302, doi:10.1029/2008JD010126.

## • RECENT TEACHING EXPERIENCE •

*2010:* ESPM 3425: Atmospheric Composition: From Smog to Climate Change - *University of Minnesota*
*2010:* LAAS 5480: Atmospheric Processes II (Radiation, Chemistry, Climate) - *University of Minnesota*
*2008, 2009:* ESPM 1425: The Atmosphere - *University of Minnesota*

## • EXAMPLES OF UNIVERSITY AND COMMUNITY SERVICE •

- GEOS-Chem Steering Committee Member; co-chair of Working Group on Carbon Gases & Organics (2009-present)
- Session convener, AGU Fall Meeting, San Francisco (2010): *Measuring Earth-Atmosphere Fluxes and Tropospheric Composition from Space*
- State representative, National Atmospheric Deposition Program (NADP) (2009-present)
- Graduate committee, Land and Atmospheric Science, UMN (2009-present)

## • OTHER SYNERGISTIC ACTIVITIES •

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|---|---|
| Reviewer: | NSF, NOAA, J. Geophys. Res., Geophys. Res. Lett., Environ. Sci. Technol., IPCC, Atmos. Environ., Atmos. Chem. Phys., Canadian Foundation for Climate and Atmospheric Sciences, others. |
| Member: | American Geophysical Union, American Chemical Society |

## • RESEARCH ADVISEES •

Lu Hu (PhD; 2008-present); Nik Boeke (PhD; 2008-present); Wes Reinhart (BS, 2010-present); Michael Mohr (BS; 2008-present); Kelley Wells (postdoc; starts 9/2010); Su Youn Kim (postdoc; starts 9/2010).

# Kristina M. Wagstrom

## EDUCATION

***Doctor of Philosophy in Chemical Engineering***, Department of Chemical Engineering, *Carnegie Mellon University,* Pittsburgh, PA, 2009
Focus Area: Atmospheric Sciences
Dissertation Title: Characterizing the Origin of Atmospheric Particulate Matter
Dissertation Advisor: Dr. Spyros N. Pandis
***Bachelor of Science in Chemical Engineering***, Chemical and Environmental Engineering Department, *Illinois Institute of Technology*, Chicago, IL, 2004
***Bachelor of Science in Chemistry***, Biological, Chemical and Physical Sciences Department, *Illinois Institute of Technology*, Chicago, IL, 2004

## RESEARCH EXPERIENCE

***Postdoctoral Associate***, Department of Civil Engineering, *University of Minnesota*, Minneapolis, MN, August 2009 – current
***Undergraduate Researcher***, Chemical and Environmental Engineering Department, *Illinois Institute of Technology*, Chicago, IL, 2002-2004
***Undergraduate Researcher***, Biological, Chemical and Physical Sciences Department, *Illinois Institute of Technology*, Chicago, IL, 2002-2003
***Summer Researcher***, Analytical Laboratory, Nuclear Technologies Division, *Argonne National Laboratory - West*, Idaho Falls, ID, 2003 (now Idaho National Laboratory)

## PUBLICATIONS

Roy, Anirban A., Wagstrom, Kristina M., Weitkamp, Emily A., Lambe, Andrew T., Adams, Peter A., Pandis, Spyros N., Robinson, Allen L. Effect of Heterogeneous Oxidation of Motor Vehicle Molecular Markers on Organic Carbon Source Apportionment. (2010) *Atmospheric Environment.* Submitted.

Wagstrom, Kristina M., Pandis, Spyros N. Contributions of Long Range Transport to Local Fine Particulate Matter Problems. (2010) *Atmospheric Chemistry and Physics.* Submitted.

Wagstrom, Kristina M., Pandis, Spyros N. Source-Receptor Relationships for Fine Particulate Matter in the Eastern United States. (2010) *Atmospheric Environment.* Submitted.

Wagstrom, Kristina M., Pandis, Spyros N. Determination of the Age Distribution of Aerosol Species Using a Chemical Transport Model. (2009) *Journal of Geophysical Research - Atmospheres*. 114.

Wagstrom, Kristina M., Pandis, Spyros N., Yarwood, Greg, Wilson, Gary M., Morris, Ralph E. Development and Application of a Computationally Efficient Apportionment Algorithm in a Three Dimensional Chemical Transport Model. (2008) *Atmospheric Environment.* 42 (22). 5650-5659.

## PRESENTATIONS

***Oral Presentations***

Wagstrom, Kristina M.,Tessum, Chris, Hill, Jason, Marshall, Julian. Air Pollution Impacts of Conventional and Alternative Fuels. *American Association for Aerosol Research's 29th Annual Conference*. October 25-29, 2010. Portland, OR. *Accepted*.

Roy, Anirban, Wagstrom, Kristina M., Pandis, Spyros N., Adams, Peter, Robinson, Allen L. Investigating the Effects of Heterogeneous Oxidation on Organic Molecular Markers Concentrations. *American Association for Aerosol Research's 29th Annual Conference*. October 25-29, 2010. Portland, OR. *Accepted*.

Wagstrom, Kristina M., Pandis, Spyros N. Contribution of Long Range Transport to Local Fine Particulate Matter Problems. *American Association for Aerosol Research's 28th Annual Conference*. October 26-30, 2009. Minneapolis, MN.

Wagstrom, Kristina M., Pandis, Spyros N. Evaluation of Long-Range Transport of Atmospheric Particulate Matter Using a Regional Chemical Transport Model. *2008 American Institute of Chemical Engineers Annual Meeting*. November 16-21, 2008. Philadelphia, PA.

Wagstrom, Kristina M., Pandis, Spyros N. Determination of Atmospheric Aerosol Age Using a Three-Dimensional Eulerian Model. *American Association for Aerosol Research's 27th Annual Conference*. October 20-24, 2008. Orlando, FL.

Wagstrom, Kristina M., Pandis, Spyros N. Determination of Atmospheric Aerosol Age Using a Three-Dimensional Eulerian Model. *European Aerosol Conference 2008*. August 24-29, 2008. Thessaloniki, Greece.

Wagstrom, Kristina M., Pandis, Spyros N. Application of an Apportionment Algorithm to Studying Source Influences in the Eastern United States. *Air and Waste Management Association's 100th Annual Conference.* June 26-28, 2007. Pittsburgh, PA.

Wagstrom, Kristina M., Pandis, Spyros N., Yarwood, Greg, Wilson, Gary M., Morris, Ralph E. Development and Application of a Computationally Efficient Apportionment Algorithm in a Three Dimensional Chemical Transport Model. *2006 International Aerosol Conference*. September 10-15, 2006. St. Paul, MN.

## FELLOWSHIPS AND AWARDS

***EPA STAR (Science To Achieve Results) Graduate Student Fellowship***, *US EPA*. 2007-2009. $69,000.
***Third Place Doctoral, Student Poster Competition***, *Air & Waste Management Association*. 2008.
***Make the Connection Volunteerism Award***, *NAWBO Pittsburgh Chapter*, 2008.
In recognition of service to Gwen's Girls, an organization serving at-risk female populations
***Lubrizol Graduate Fellowship***, *Carnegie Mellon University*. 2007. $8,200.