

## *Curriculum Vitae*

# Drew T. Shindell

Nicholas School of the Environment, Duke University



## **EDUCATION**

Ph.D. (Physics), State University of New York at Stony Brook, 1995  
B.A. (Physics), University of California at Berkeley, 1988

## **EMPLOYMENT**

2016-present: Nicholas Distinguished Professor of Earth Sciences, Duke University  
2021-2022: UNEP/CCAC Special Advisor for Methane Action  
2019-present: Professor by Special Appointment, Porter School of the Environment and Earth Sciences, Tel Aviv University  
2015-present: Senior Scientist (Climate Sciences), UN Environment  
2014-2016: Professor of Climate Sciences, Duke University  
1997-2014: Physical Scientist, NASA Goddard Institute for Space Studies, NYC  
1997-2010: Lecturer, Dept. of Earth and Environmental Sci., Columbia University  
1995-1997: NASA EOS Postdoctoral Researcher, Columbia Univ. & NASA GISS

## **RESEARCH INTERESTS**

Sensitivity of climate change to different drivers  
Climate and air quality linkages and public policy  
Interdisciplinary assessment of the impact of policy options on climate, public health, food and the economy  
Atmospheric composition changes and solar power generation

## **PROFESSIONAL EXPERIENCE**

Chair, Scientific Advisory Panel to the Climate and Clean Air Coalition (~70 nations plus various IGOs and NGOs), 2012-present  
EPA Science Advisory Board Member, 2021-2023  
Chair, Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions, Climate and Clean Air Coalition & United Nations Environment Programme, 2019-2021  
Chapter co-lead, “The role of anthropogenic methane emissions in bridging the emissions gap”, UNEP Emissions Gap Report, 2021  
Coordinating Lead Author, “Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development” chapter, Intergovernmental Panel on Climate Change Special Report on 1.5°C, 2018  
Contributing Author, “Strengthening and Implementing the Global Response”, Intergovernmental Panel on Climate Change Special Report on 1.5°C, 2018

Scientific Advisor & Plenary Speaker, First WHO Global Conference on Air Pollution and Health: *Improving Air Quality, Combatting Climate Change – Saving Lives*, Geneva, Switzerland, 2018

AAAS Atmospheric and Hydrological Sciences Section Elected Member-at-large, 2016-2019

Technical Advisory Group to the International Standards Organization, US delegation member, 2017-2019

Chapter co-lead, “Short-Lived Climate Pollutants”, UNEP Emissions Gap Report, 2017

Foreign Expert, China Council for International Cooperation on Environment and Development, Special Policy Study: Coordinated Actions for Addressing Climate Change and Air Pollution, 2014-2015.

Review Panel, NOAA Office of Atmospheric Research, Laboratory Review, 2014

Coordinating Lead Author, Anthropogenic and Natural Radiative Forcing chapter, Intergovernmental Panel on Climate Change Fifth Assessment Report, 2011-2013

Contributing Author, 3 chapters (Long-term Climate Change: Projections, Commitments and Irreversibility; Detection and Attribution of Climate Change: from Global to Regional; and Evaluation of Climate Models), IPCC Fifth Assessment Report, 2013

Originator & Co-Lead, Atmospheric Chemistry and Climate Model Intercomparison Project, 2009-2013

Chair, Integrated Assessment of Black Carbon and Tropospheric Ozone, UN Environment Programme & World Meteorological Organization, 2009-2011

Member, National Academy of Sciences Assessment of the Effects of US Tax Policy on Greenhouse Gas Emissions, 2011-2013

Member, National Academy of Sciences Assessment of Himalayan Glaciers: Climate Change, Water Resources, and Water Security, 2011-2012

Co-Editor, Atmospheric Chemistry and Physics, 2009-2014

Co-Chair, US Climate Change Science Program Synthesis & Assessment Product 3.2: Climate Projections Based on Emissions Scenarios for Long-Lived and Short-Lived Radiatively Active Gases and Aerosols, 2006-2008

Co-author, Arctic Climate Impacts Assessment, 2005

Co-author, UNEP/WMO Scientific Assessment of Ozone Depletion, 1998, 2002, 2006

AGU Atmospheric Physics and Climate Section Secretary, 2002-2004

## PUBLIC OUTREACH/GOVERNMENT/MEDIA

Education: Co-creator of ‘Climate Change Science’ course offered by American Museum of Natural History (AMNH) to middle & high school teachers. Consultant on AMNH exhibits.

Government: Testimony delivered to both houses of the US Congress, US EPA, US National Academy, US State Dept., Arctic Council, UNFCCC, etc.

Media: Numerous outreach activities including interviews and appearances on NOVA, NPR, BBC, CBC, CNN, New York Times, Washington Post, etc.

## AWARDS & HONORS

Clarivate Analytics “Highly Cited Researcher”, 2010-present  
AAAS Fellow, 2015  
AGU Fellow, 2014  
US EPA Scientific and Technological Achievement Award, 2013  
MIT Henry Kendall Honorary Lecturer, 2013  
NCAR Earth System Research Laboratory Distinguished Lecturer, 2013  
AGU Atmospheric Science Charney Lecturer, Fall meeting, 2012  
Ne’eman Distinguished Lecturer, Tel Aviv University, 2012  
Scientific American ‘Top 50’ Scientists, 2004  
NASA GISS ‘Best Popular Science Article’ peer award, 2002 and 2011  
NASA GISS ‘Publication of the Year’ peer award, 1998, 1999 and 2012  
National Science Foundation, Antarctic Service Medal, 1994

## MENTORING

PhD: K. Seltzer, T. Tang, M. Ru  
Postdoctoral: J. Lee Grenfell (now at Free U Berlin), Volker Grewe (now at DLR), Nadine Unger (now at U Exeter), Daven Henze (now at U Colorado), Apostolos Voulgarakis (now at U Crete), Pavan Racherla (now at NextClimate), Olga Pechony, Yunha Lee (now at U Washington), Melissa Scott (Duke), Luke Parsons (current)  
Thesis committee: Mark Potosnak (Columbia), Sun Wong (Columbia), Jae Lee (Stony Brook), Ben Kravitz (Rutgers), Miriam Marlier (Columbia), Justin Wood (Murdoch), Michael Valerino (Duke –Engineering), Tongshu Zheng (Duke –Engineering), Patrick Brown (Duke –Environment), Linda Low (Duke –Public Policy), Colleen Baublitz (Columbia), plus many Duke Masters’ students

## GRANTS

Funding as PI from NASA’s Atmospheric Chemistry Modeling and Analysis Program (1998, 2003, 2006, 2010, 2017); NASA Applied Sciences program (2008); NASA Living with a Star (2009), NASA National Climate Assessment (2011, 2013), NASA Aura Science (2014); NASA SORCE (2015); NASA GISS (2015; 2019); NSF (2000, 2014); California Air Resources Board (2008); US EPA (2010); US DoT (2014); Pisces Foundation (2016), Rockefeller Foundation (2019 – co-I). Co-I on numerous NSF and NASA proposals.

## PEER-REVIEWED PUBLICATIONS

- 288 Zhang, Y., D. Shindell, K. Seltzer, L. Shen, J.-F. Lamarque, Q. Zhang, B. Zheng, J. Xing, Z. Jiang, L. Zhang, Impacts of emission changes in China from 2010 to 2017 on domestic and intercontinental air quality and health effect, *Atmos. Chem. Phys.*, in press, 2021.  
287 Parsons, L. A., D. Shindell, M. Tigchelaar, Y. Zhang, J. T. Spector, Increased labor losses and decreased adaptation potential in a warmer world, *Nature Comms.*, in press, 2021.  
286 Shindell, D., M. Ru, Y. Zhang, K. Seltzer, G. Faluvegi, L. Nazarenko, G. A. Schmidt, L. Parsons, A. Challapalli, L. Yang, A. Glick, Temporal and Spatial Distribution of Health, Labor and

- Crop Benefits of Climate Change Mitigation in the US, *Proc. Natl. Acad. Sci.*, in press, 2021.
- Murray, L., A. M. Fiore, D. T. Shindell, V. Naik, L. W. Horowitz, Large uncertainties in global hydroxyl projections tied to fate of reactive nitrogen and carbon, *Proc. Natl. Acad. Sci.*, in press, 2021.
- Misios, S., et al., Similar patterns of tropical precipitation and circulation changes under solar and greenhouse gas forcing, *Env. Res. Lett.*, in press, 2021.
- Tang, T., Drew Shindell, Yuqiang Zhang, Apostolos Voulgarakis, Jean-Francois Lamarque, Gunnar Myhre, Gregory Faluvegi, Bjørn H. Samset, Timothy Andrews, Dirk Olivié, Toshihiko Takemura, Xuhui Lee, Distinct surface response to black carbon aerosols, *Atmos. Chem. Phys.*, 21, 13797–13809, 2021.
- United Nations Environment Programme and Climate and Clean Air Coalition, Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions, Nairobi, Kenya, United Nations Environment Programme, 2021.
- Malley, C. S., W. K. Hicks, J. Kulyenstierna, J. Veysey, C. G. Heaps, S. Ulloa, E. Michalopoulou, J. Slater, A. Molotoks, D. Shindell, D. K. Henze, S. C. Anenberg, Integrated assessment of global climate, air pollution, and dietary, malnutrition and obesity health impacts of food production and consumption between 2014 and 2018, *Env. Res. Comm.*, 3, 075001, 2021.
- Ocko, I. B., T. Sun, D. Shindell, M. Oppenheimer, A. N. Hristov, S. W. Pacala, D. L. Mauzerall, Y. Xu, S. P. Hamburg, Acting rapidly to deploy readily available methane mitigation measures by sector can immediately slow global warming, *Env. Res. Lett.*, 16, 054042, 2021.
- Ru, M., M. Brauer, J-F. Lamarque, D. Shindell, Exploration of the global burden of dementia attributable to PM2.5: what do we know based on current evidence?, *GeoHealth*, 5, e2020GH000356, 2021.
- Sherman, P., M. Gao, S. Song, A. T. Archibald, N. L. Abraham, J.-F. Lamarque, D. Shindell, G. Faluvegi, M. B. McElroy, Sensitivity of modeled Indian Monsoon to Chinese and Indian aerosol emissions, *Atmos. Chem. Phys.*, 21, 3593-3605, 2021.
- Zhang, Y., Shindell, D., Costs from labor losses due to extreme heat in the United States attributable to climate change, *Clim. Change*, 164:35, 2021.
- Derwent, R. G., Parrish, D., Archibald, A., Deushi, M., Bauer, S., Tsagiris, K., Shindell, D., Horowitz, L., Khan, A., Shallcross, D., Intercomparison of the representations of the atmospheric chemistry of pre-industrial methane and ozone in earth system and other global chemistry-transport models, *Atm. Environ.*, 248, 118248, 2021.
- Miller, R., et al., CMIP6 Historical Simulations (1850–2014) with GISS-E2.1, *J. Adv. Model. Earth Syst.*, 13, e2019MS002034, 2021.
- Hess, J., et al., Guidelines for Modeling and Reporting Health Effects of Climate Change Mitigation Actions, *Env. Health Persp.*, 128, 115001, doi:10.1289/EHP6745, 2020.
- Hodnebrog, Ø, et al., The effect of rapid adjustments to halocarbons and N<sub>2</sub>O on radiative forcing, *npj Clim. Atmos. Sci.*, 3, 43, 2020.
- Kuylenstierna, J., et al., Development of the Low Emissions Analysis Platform – Integrated Benefits Calculator (LEAP-IBC) tool to assess air quality and climate co-benefits: Application for Bangladesh, *Env. Intl.*, 145, 106155, 2020.
- Morgenstern, O., et al., Reappraisal of the climate impacts of ozone-depleting substances, *Geophys. Res. Lett.*, 47, e2020GL088295, 2020.
- Xing, J., Lu, X., Wang, S., Wang, T., Ding, D., Yu, S., Shindell, D., Ou, Y., Morawska, L., Li, S., Ren, L., Zhang, Y., Loughlin, D., Hao, J., The quest for improved air quality may push China to continue its CO<sub>2</sub> reduction beyond the Paris Commitment, *Proc. National Acad. Sci.*, 117, 29535-29542, 2020.
- Miyazaki, K., K. Bowman, T. Sekiya, Z. Jiang, X. Chen, H. Eskes, M. Ru, Y. Zhang, and D. Shindell, Air quality response in China linked to the 2019 novel Coronavirus (COVID-19) lockdown, *Geophys. Res. Lett.*, 47, e2020GL089252, 2020.
- Stjern, C. W., et al., How aerosols and greenhouse gases influence the diurnal temperature range, *Atmos. Chem. Phys.*, 20, 13467–13480, 2020.
- Shindell, D., Y. Zhang, M. Scott, M. Ru, K. Stark, K. L. Ebi, The Effects of Heat Exposure on Human Mortality Throughout the US, *GeoHealth*, 3, e2019GH000234, 2020.
- Xie, X., et al., Distinct responses of Asian summer monsoon to black carbon aerosols and

- greenhouse gases, *Atmos. Chem. Phys.*, 20, 11823–11839, 2020.
- 265 Orbe, C., et al., GISS Model E2.2: A Climate Model Optimized for the Middle Atmosphere. Part 2: Validation of Large-Scale Transport and Evaluation of Climate Response, *J. Geophys. Res.*, 125, e2020JD033151, 2020.
- 264 Kelley, M., et al., GISS-E2.1: Configurations and Climatology, *J. Adv. Model. Earth Syst.*, 12, e2019MS002025, 2020.
- 263 Tang, T., D. Shindell, Y. Zhang, A. Voulgarakis, J.-F. Lamarque, G. Myhre, C. W. Stjern, G. Faluvegi, B. H. Samset, Response of surface shortwave cloud radiative effect to greenhouse gases and aerosols and its impact on summer maximum temperature, *Atmos. Chem. Phys.*, 20, 8251–8266, 2020.
- 262 Agrawala, S., Amann, M., Binimelis de Raga, G., Borgford-Parnell, N., Brauer, M., Clark, H., Emberson, L., Haines, A., Kejun, J., Kunzli, N., Kuylenstierna, J., Lacy, R., Liu, J., Mulugetta, Y., Pachauri, S., Ramanathan, V., Ravishankara, A. R., Shindell, D., Wongwangwatana, S., Call for comments: climate and clean air responses to covid-19, *Intl. J. Public Health*, 2020.
- 261 Shindell, D., G. Faluvegi, G. Schmidt, Influences of solar forcing at ultraviolet and longer wavelengths on climate, *J. Geophys. Res.*, 124, e2019JD031640, <https://doi.org/10.1029/2019JD031640>, 2020.
- 260 Skeie, R., et al., Historical total ozone radiative forcing derived from CMIP6 simulations, *npj Clim. Atmos. Sci.*, 3, 32, <https://doi.org/10.1038/s41612-020-00131-0>, 2020.
- 259 Rind, D., et al., GISS Model E2.2: A Climate Model Optimized for the Middle Atmosphere. Part 1: Model Structure, Climatology, Variability and Climate Sensitivity, *J. Geophys. Res.*, 125, e2019JD032204, 2020.
- 258 Seltzer, K., Shindell, D. T., P. Kasibhatla, and C. S. Malley, Magnitude, Trends, and Impacts of Ambient Long-Term Ozone Exposure in the United States from 2000- *Atmos. Chem. Phys.*, 20, 1757-1775, 2020.
- 257 Westervelt, D., N. R. Mascioli, A. M. Fiore, A. J. Conley, J.-F. Lamarque, C. Tebaldi, D. T. Shindell, G. Faluvegi, G. Correa, L. W. Horowitz, Local and remote mean and extreme temperature response to regional aerosol emissions reductions, *Atmos. Chem. Phys.*, 20, 3009–3027, 2020.
- 256 Richardson, T. B., Forster, P. M., Smith, C. J., Maycock, A. C., Wood, T., Andrews, T., et al., Efficacy of climate forcings in PDRMIP models, *J. Geophys. Res.*, 124, 12,824-12,844, 2019.
- 255 Shindell, D., C. J. Smith, Climate and air-quality benefits of a realistic phase-out of fossil fuels, *Nature*, 573, 408-411, doi: 10.1038/s41586-019-1554-z, 2019.
- 254 Andrade, MD, et al., Academy of Science of South Africa, Brazilian Academy of Sciences, German National Academy of Sciences Leopoldina, U. S. National Academy of Medicine and U. S. National Academy of Sciences, Air Pollution and Health – A Science-Policy Initiative, *Annals of Global Health*, 85, 140, 1-9, 2019.
- 253 Tallis, H., et al, Aligning Evidence Generation and Use Across Health, Development, and Environment, *Curr. Opinion Env. Sust.*, 39, 81-93, 2019.
- 252 Sillmann, J., Stjern, C.W., Myhre, G. Samset, B.H., Hodnebrog, Ø., Andrews, T., Boucher, O., Faluvegi, G., Forster, P., Kasoar, M.R., Kharin, V.V., Kirkevag, A., Lamarque, J.-F., Olivie, D. J. L., Richardson, T. B., Shindell, D., Takemura, T., Voulgarakis, A., and Zwiers, F. W., Extreme wet and dry conditions affected differently by greenhouse gases and aerosols, *npj Clim. Atmos. Sci.*, 2, 24, doi:10.1038/s41612-019-0079-3, 2019.
- 251 Hodenbrog, O, et al, Water vapor adjustments and responses differ between climate drivers, *Atmos. Chem. Phys.*, 19, 12887-12899, 2019.
- 250 Shindell, D., G. Faluvegi, P. Kasibhatla, R. Van Dingenen, Spatial patterns of crop yield change by emitted pollutant, *Earth's Future*, 7, 101-112, doi:10.1029/2018EF001030, 2019.
- 249 Tang, T., Shindell, D., et al., Comparison of Effective Radiative Forcing Calculations using Multiple Methods, Drivers, and Models, *J. Geophys. Res.*, 124, 4382-4394, 2019.
- 248 Allen, R. J., A. Amiri-Farahani, J.-F. Lamarque, C. Smith, D. Shindell, T. Hassan, C. E. Chung, Observationally-constrained aerosol-cloud semi-direct effects, *npj Climate Atm. Sci.*, 2, 16, doi:10.1038/s41612-019-0073-9, 2019.
- 247 Stjern, C., et al., Arctic amplification response to individual climate drivers, *J. Geophys. Res.*, 124, 6698-6717, doi:10.1029/2018JD029726, 2019.
- 246 Aas, W., et al., Global and regional trends of atmospheric sulfur, *Sci. Rep.*, 9, 953, 2019.

- 245 Richardson, T. B., et al., Drivers of precipitation change: An energetic understanding, *J. Climate*, 31, 9641-9657, 2018.
- 244 IPCC, Summary for Policymakers. In: Global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, et al (eds.)]. World Meteorological Organisation, Geneva, Switzerland, 2018.
- 243 Rogelj, J., D. Shindell, J. Jiang, et al., Mitigation Pathways compatible with 1.5°C in the context of sustainable development, in Special Report on Global Warming of 1.5°C, Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2018.
- 242 UN Environment, Air Pollution in Asia and the Pacific: Science-based Solutions, Nairobi, Kenya, 58 pp., 2018.
- 241 Ru, M., D. Shindell, K. Seltzer, S. Tao, Q. Zhong, The long-term relationship between emissions and economic growth for SO<sub>2</sub>, CO<sub>2</sub> and BC, *Env. Res. Lett.*, 13, 124021, 2018.
- 240 Fiore, A., et al., Peroxy acetyl nitrate (PAN) measurements at northern midlatitude mountain sites in April: a constraint on continental source–receptor relationships, *Atmos. Chem. Phys.*, 18, 15345-15361, 2018.
- 239 Smith, C., et al., Understanding rapid adjustments to diverse forcing agents, *Geophys. Res. Lett.*, 45, 12023-12031, doi:10.1029/2018GL079826, 2018.
- 238 Myhre, G., et al., Quantifying the importance of rapid adjustments for global precipitation changes, *Geophys. Res. Lett.*, 45, 11,399-11,405, 2018.
- 237 Seltzer, K., D. Shindell, C. Malley, Measurement-based assessment of health burdens from long-term ozone exposure in the United States, Europe, and China, *Env. Res. Lett.*, 13, 104018, 2018.
- 236 Shindell, D., G. Faluvegi, K. Seltzer, C. Shindell, Quantified, Localized Health Benefits of Accelerated Carbon Dioxide Emissions Reductions, *Nature Climate Change*, 8, 291-295, 2018.
- 235 Jeuland, M., J.-S. T. Soo, and D. Shindell, The Need for Policies to Reduce the Costs of Cleaner Cooking in Low Income Settings: Implications from Systematic Analysis of Costs and Benefits, *Energy Policy*, 121, 275-285, 2018.
- 234 Alvarado, M., E. Winikul, R. Adams-Selin, E. Hunt, C. Brodowski, C. R. Lonsdale, D. T. Shindell, G. Faluvegi, G. Kleiman, T. M. Mosier, and R. Kumar, Sources of Black Carbon Deposition to the Himalayan Glaciers in Current and Future Climates, *J. Geophys. Res.*, 123, 7482-7505, 2018.
- 233 Westervelt, D. M., A. J. Conley, A. M. Fiore, J.-F. Lamarque, D. T. Shindell, M. Previdi, N. R. Mascioli, G. Faluvegi, G. Correa, L. W. Horowitz, Connecting regional aerosol emissions reductions to local and remote precipitation responses, *Atmos. Chem. Phys.*, 18, 12461-12475, 2018.
- 232 Tang, T., et al., Dynamical response of Mediterranean precipitation to greenhouse gases and aerosols, *Atmos. Chem. Phys.*, 18, 8439–8452, 2018.
- 231 Integrated Assessment of Short-lived Climate Pollutants in Latin America and the Caribbean, Climate and Clean Air Coalition, Paris, 101 pp., 2018.
- 230 Myhre, G., et al., Sensible heat has significantly affected the global hydrological cycle over the historical period, *Nature Comm.*, DOI:10.1038/s41467-018-04307-4, 2018.
- 229 Conley, A. J., Westervelt, D. M., Lamarque, J.-F., Fiore, A. M., Shindell, D., Correa, G., Faluvegi, G., and Horowitz, L. W., Multimodel surface temperature responses to removal of U.S. sulfur dioxide emissions, *J. Geophys. Res.*, 123, 2773-2796, 2018.
- 228 Liu, L., et al., A PDRMIP multi-model study on the impacts of regional aerosol forcings on global and regional precipitation, *J Climate*, 31, 4429-4447, 2018.
- 227 Richardson, T. B., et al., Carbon dioxide physiological forcing dominates projected Eastern Amazonian drying, *Geophys. Res. Lett.*, 45, 2815–2825, 2018.
- 226 Fuglestvedt, J., Rogelj, J., Millar, R.J., Allen, M., Boucher, O., Cain, M., Forster, P.M., Kriegler, E., Shindell, D., Implications of possible interpretations of ‘greenhouse gas balance’ in the Paris Agreement, *Phil. Trans. R. Soc. A*, 20160445, doi:10.1098/rsta.2016.0445, 2018.
- 225 Samset, B. H., G. Myhre, P. M. Forster, Ø. Hodnebrog, T. Andrews, O. Boucher, G. Faluvegi, D.

- Fläschner, M. Kasoar, V. Kharin, A. Kirkevåg, J.-F. Lamarque, D. Olivié, T. Richardson, D. Shindell, T. Takemura, A. Voulgarakis, Weak hydrological sensitivity to temperature change over land, independent of climate forcing, *npj Climate and Atm. Sci.*, 3, doi:10.1038/s41612-017-0005-5, 2018.
- 224 Shindell, D. T., N. Borgford-Parnell, M. Brauer, A. Haines, J. C. I. Kylenstierna, S. A. Leonard, V. Ramanathan, A. Ravishankara, M. Amann, L. Srivastava, A climate policy pathway for near- and long-term benefits, *Science*, 356, 493-494, 2017.
- 223 Seltzer, K., Shindell, D. T., Faluvegi, G., & Murray, L.T., Evaluating modeled impact metrics for human health, agriculture growth, and near-term climate, *J. Geophys. Res.*, 122, 13,506-13,524, <https://doi.org/10.1002/2017JD026780>, 2017.
- 222 Kumar, R., V. Mishra, J. Buzan, R. Kumar, D. Shindell, M. Huber, Dominant control of agriculture and irrigation on urban heat island in India, *Scientific Reports*, 7, 14054, doi:10.1038/s41598-017-14213-2, 2017.
- 221 Doherty, R. M., C. Orbe, G. Zeng, M. Prather, D. A. Plummer, M. Lin, D. Shindell, I. A. Mackenzie1, O. Wild, Multi-model Impacts of Climate Change on Pollution Transport from Global Emission Source Regions, *Atmos. Chem. Phys.*, 17, 14219-14237, 2017.
- 220 Stjern, C. W., B. H. Samset, G. Myhre, P. M. Forster, Ø. Hodnebrog, T. Andrews, O. Boucher, G. Faluvegi, T. Iversen, M. Kasoar, V. Kharin, A. Kirkevåg, J.-F. Lamarque, D. Olivié, T. Richardson, D. Shawki, D. Shindell, C. J. Smith, T. Takemura, A. Voulgarakis, F. Zwiers, Rapid adjustments cause weak surface temperature response to increased black carbon concentrations, *J. Geophys. Res.*, 122, 11,462–11,481, 2017.
- 219 Haines, A., M. Amann, N. Borgford-Parnell, S. Leonard, J. C. I. Kylenstierna, D. Shindell, Short-lived climate pollutant mitigation and the sustainable development goals, *Nature Climate Change*, 7, 863-869, 2017.
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- 214 Shindell, D., J. S. Fuglestvedt, W. J. Collins, The Social Cost of Methane: Theory and Applications, *Faraday Disc.*, 200, 429-451, doi: 10.1039/C7FD00009J, 2017.
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- 212 Westervelt, D.M., A.J. Conley, A.M. Fiore, J.-F. Lamarque, D. Shindell, M. Previdi, G. Faluvegi, G. Correa, L.W. Horowitz, Multi-model precipitation responses to removal of U.S. sulfur dioxide emissions, *J. Geophys. Res.*, 122, 5024–5038, 2017.
- 211 Myhre, G., Aas, W., Cherian, R., Collins, W., Faluvegi, G., Flanner, M., Forster, P., Hodnebrog, Ø., Klimont, Z., Lund, M. T., Mülmenstädt, J., Lund Myhre, C., Olivié, D., Prather, M., Quaas, J., Samset, B. H., Schnell, J. L., Schulz, M., Shindell, D., Skeie, R. B., Takemura, T., and Tsyro, S.: Multi-model simulations of aerosol and ozone radiative forcing due to anthropogenic emission changes during the period 1990–2015, *Atmos. Chem. Phys.*, 17, 2709-2720, 2017.
- 210 Collins, W. J., J.-F. Lamarque, M. Schulz, O. Boucher, V. Eyring, M. I. Hegglin, A. Maycock, G. Myhre, M. Prather, D. Shindell, S. J. Smith, AerChemMIP: Quantifying the effects of chemistry and aerosols in CMIP6, *Geosci. Model. Dev.*, 10, 585-607, 2017.
- 209 Myhre, G., P. M. Forster, B. H. Samset, Ø. Hodnebrog, J. Sillmann, T. Andrews, O. Boucher, G.

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