Air Pollution and Health Co-Benefits of the Paris Agreement on Climate Change: Methodology

Kathleen M. Mulvaney[1*], Steven J. Smith[2,3], Haewon C. McJeon[2], J. Jason West[1]

[1]Department of Environmental Sciences and Engineering, University of North Carolina (UNC) at Chapel Hill, Chapel Hill, NC; [2]Joint Global Change Research Institute, Pacific Northwest National Lab, College Park, MD; [3]Department of Atmospheric and Oceanic Science, University of Maryland, College Park, MD; *Contact: katmm@live.unc.edu

The Paris Agreement on climate change is an international, legally binding treaty between 197 member countries, and it entered into force in November 2016 [1]. Under the Paris Agreement, member countries submit Nationally Determined Contributions (NDCs) every five years outlining plans to mitigate greenhouse gas emissions (GHGs) and strengthen national climate resilience [2, 3]. Actions to mitigate GHGs that reduce energy system reliance on fossil fuels can achieve significant reductions in other air pollutants that impact human health, such as ozone and particulate matter smaller than 2.5 microns ($PM_{2.5}$) [4]. Air pollution reductions and improved health outcomes resulting from policies that target GHG mitigation are considered co-benefits.

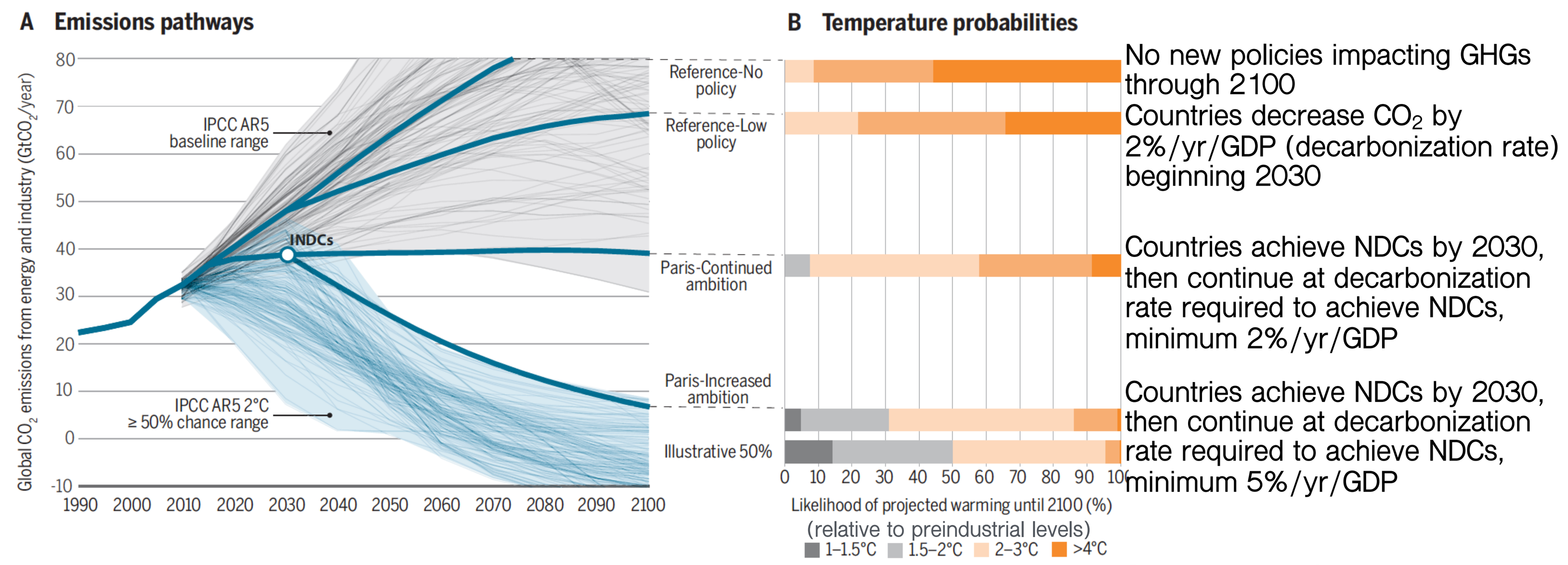
Research Questions

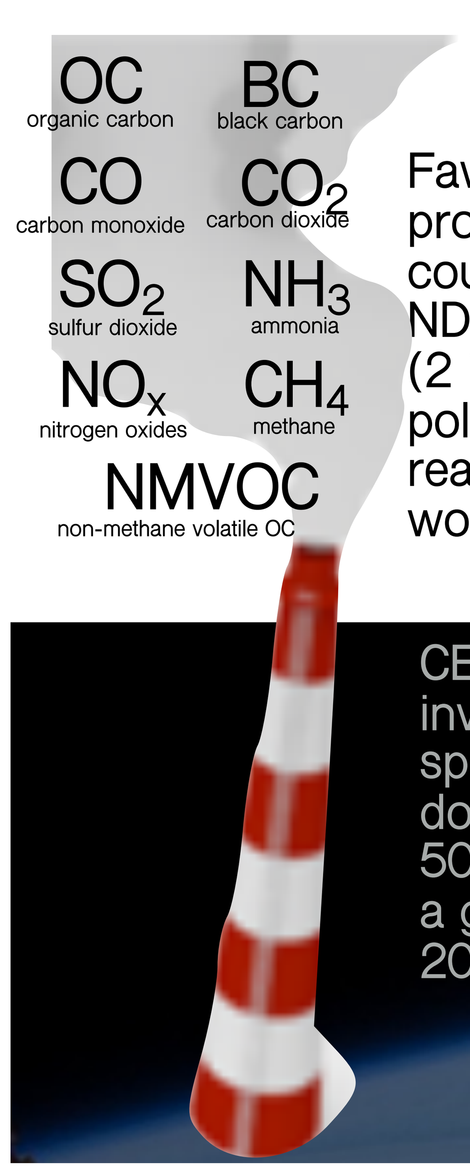
- How could the Nationally Determined Contributions (NDCs), pledges submitted by member countries under the Paris Agreement on climate change, impact global $PM_{2.5}$ and ozone concentrations, considering the impacts of a changing climate on air quality?
- Relative to a baseline scenario where less stringent policy is implemented, to what extent could the Paris Agreement contribute to avoided premature mortality from respiratory diseases, cardiopulmonary diseases, and lung cancer?
- How does the United States NDC impact air pollution and health co-benefits in other world regions? Conversely, how do NDCs from the rest of the world impact air pollution and health co-benefits in the United States?

Emissions Scenarios

We will harmonize future Global Change Assessment Model (GCAM) precursor emissions from the Fawcett et al. [5] policy scenarios with a 2015 Community Emissions Data System (CEDS) inventory, creating emissions scenarios for two Reference policy scenarios and three Paris Agreement policy scenarios at 0.5˚x0.5˚ resolution to be used with CESM2.0.0.

From Fawcett et al., Ref. [5]





Fawcett et al. [5] used GCAM, an integrated assessment model providing data on economic activity and energy systems at the country and sector level, to evaluate the probability that the NDCs will achieve the Paris Agreement's temperature rise goal (2 ˚C, with efforts to achieve 1.5 ˚C). GCAM also calculates air pollution precursor emissions, which undergo chemical reactions in the atmosphere to form ozone and $PM_{2.5}$, for 16 world regions and a wide range of economic sectors.

CEDS is open-source software that creates historical emission inventories based on economic activity data with details specific to countries, sectors, and fuel [6]. The software has downscaling capabilities that produce 0.5˚x0.5˚ (50km by 50km) gridded emissions data sets. We use CEDS to create a global set of baseline precursor emissions from the year 2015.

Evaluating Ozone and $PM_{2.5}$: Atmospheric Modeling, CESM2.0.0

The CAM6 component of CESM2.0.0 with CAM-Chem chemistry calculates global ozone and $PM_{2.5}$ concentrations at a geographic resolution of 2.0˚x2.5˚. We are considering several options to evaluate the impact of a changing climate on air quality.

CAM is the atmospheric component of the Community Earth System Model (CESM) [7]. It uses emissions inventories as inputs and has the flexibility to utilize meteorology that floats under a changing climate by interacting with the other CESM2.0.0 Earth system model components or specified dynamics from historical reanalysis meteorology (NASA's Modern-Era Retrospective Analysis for Research and Applications 2, MERRA2).

Specified Dynamics MERRA2

(CESM2 Component Set FCSD)

For each policy scenario:

2015, 2030, 2050, 2100 ->

10-yr time slices + 1 yr spinup

55 years total

Floating Meteorology Option 1, Active Land and Atmosphere, Prescribed RCP Data for Ocean, Ice

(CESM2 Component Set FC2000climo)

Ref-No-policy,	Ref-Low-policy,
Paris-Cont-amb ->	Paris-Inc-amb, Paris-No-US ->
2015-2100+1 yr spinup	2030-2100
174 years total	213 years total

Floating Meteorology Option 2, All Active CESM2 Components

(CESM2 B Component Set)

For each policy scenario:

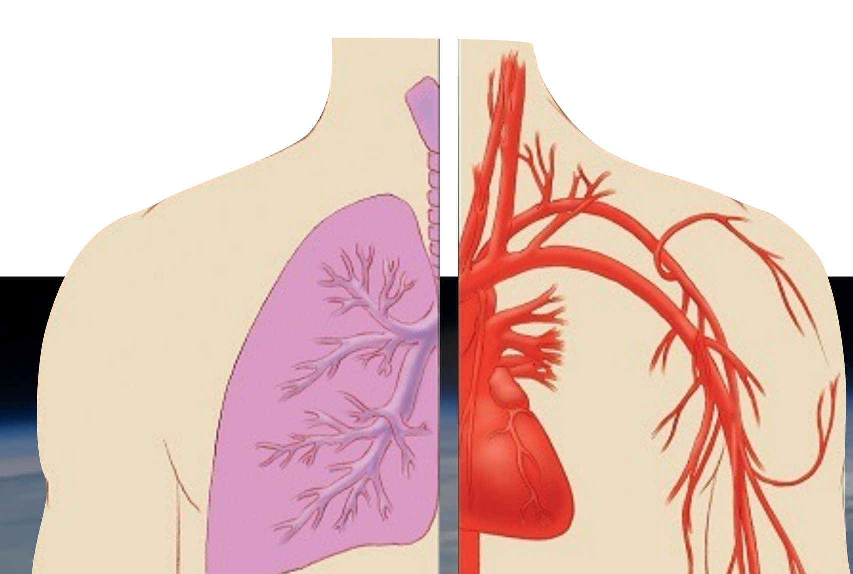
2015-2100+ 1 yr spinup

435 years total

Health Impacts: Avoided Premature Mortality

We will evaluate premature mortality from chronic respiratory diseases, ischemic heart disease, stroke, chronic obstructive pulmonary disease, and lung cancer in each grid cell. We are considering the option of using either present-day or future baseline incidence and population data.

$$\Delta Y = Y_0 * Pop * AF$$



	Y_0 Baseline Incidence	Pop Population		AF Attributable Fraction
Present Day	Global Burden of Disease [8]	CIESEN SEDAC [9]	Ozone	Jerrett et al. [11]
Future	International Futures [10]	International Futures [10]	$PM_{2.5}$	Burnett et al. [12]

References: [1] https://unfccc.int/process/the-paris-agreement/status-of-ratification; [2] UNFCCC, 2015, Paris Agreement, https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf; [3] IISD, 2015, *Earth Negotiations Bulletin*, 12(663); [4] West et al., 2013, *Nature Climate Change*; [5] Fawcett et al., 2015, *Science*; [6] Hoesly et al., 2018, *Geoscientific Model Development*; [7] Lamarque et al., 2012, *Geoscientific Model Development;* [8] Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-2016; [9] http://sedac.ciesin.columbia.edu; [10] Hughes et al., 2011, *Bulletin of the World Health Organization;* [11] Jerrett et al., 2009, *New England Journal of Medicine*; [12] Burnett et al., 2014, *Environmental Health Perspectives*

Acknowledgements: We acknowledge the support of the NASA Health and Air Quality Applied Sciences Team (HAQAST), as well as the Donald and Jennifer Holzworth Premier Fellowship in Environmental Sciences and Engineering.

Photograph from NASA Visualization Explorer, https://nasaviz.gsfc.nasa.gov/11347