Thesis Proposal - Evaluating and Extending the Arctic Monitoring and Assessment Programme (AMAP) Climate Emulator

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Computational Earth System Models (ESMs) are used to simulate projected warming, climate change, and air quality scenarios. However, they are computationally expensive, which may not be suitable for climate and air quality assessments in which the effects of multiple pollutants are considered. Climate emulators and air quality source-receptor models employ analytic relationships between emissions, concentrations, and radiative forcing, using inexpensive models that highly approximate, parametrize, and even linearize, the impacts of Earth's complex physical and chemical processes [1]. Short-lived climate forcers (SLCFs) are a group of greenhouse gases (GHGs) and other pollutants that have relatively short atmospheric lifetimes (compared to carbon dioxide) and can greatly impact climate change and air quality [2]. Due to their short lifetimes and trace amounts, which result in high uncertainties even in ESMs, emulators are a computationally inexpensive and effective tool for SLCF science in support of climate and air quality policy development [1], [2], [3].

The Arctic Monitoring and Assessment Programme (AMAP) Air Quality and Climate Emulator uses a greatly simplified ESM to predict changes in air quality and climate in five regions based on regional anthropogenic emissions of air pollutants and GHGs, including SLCFs. The tool is new and has the potential for tuning, extension, and numerous applications in climate science and policy. However, the emulator has limitations [1].

First, methane (CH4) is treated as a well-mixed GHG without spatial structure in radiative forcings or dependence on regional emission sources. Additionally, uncertainties in Arctic temperature projections resulting from uncertainties in natural CH4 emissions are high because the emulator lacks an estimate of future natural emissions [1].

A final important limitation of the emulator relates to Arctic amplification, which refers to the enhancement of changes in surface air temperature over the Arctic relative to lower latitudes [4]. The emulator has been found to underestimate Artic amplification when compared to Coupled Model Intercomparison Project Phase 6 **(**CMIP6) ESMs [1].

The purpose of this project is to better characterize and address important limitations of the AMAP emulator. First, the emulator's functionalities and output will be reviewed and evaluated, with a focus on understanding, analyzing, and tuning the climate output of the emulator in the Arctic for different CH4 scenarios [5], [6].

CH4 is modelled in the emulator as a well-mixed forcer, so to address this limitation, its atmospheric lifetime will be tweaked. Natural emissions of CH4 will also be incorporated into the emulator as a linear feedback from temperature to account for the potential increase in anaerobic respiration as a natural methane source [7]. The emulator will be run with different CH4 emissions to observe how different scenarios affect regional and global temperatures.

Biases from the ESM used to generate emulator parameters may be why the emulator projects less Arctic amplification than new CMIP6 models [1], [8]. The coefficients in the emulator will be tuned to better match recent ESM data. The regional temperature-change potential values require first-order correction. Then, the emulator will be used to study how Arctic amplification and uncertainties/biases in Arctic amplification affect the response of Arctic temperatures to SLCF and GHG emissions.

The effects of black carbon as an SLCF are also relevant to Arctic climatology [9]. Time permitting, the emulator will be run for different scenarios to observe and quantify how black carbon affects the sea ice in comparison to other climate forcers.

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