University of Reading
University of Surrey
Scenario Doctoral Training Partnership
UKRI Natural Environment Research Council

Accelerating the computation of air quality projections over India using novel computing

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Long-term exposure to air pollution can lead to a range of health issues, such as chronic respiratory diseases, heart problems, and damage to the brain and nerves. 9 out of the 10 most polluted cities in the world are in India, where poor outdoor air quality is one of the leading risk factors in premature mortality: 1 million deaths in India were attributable to poor outdoor air quality in 2019. In response to these health risks, large reductions in the emissions of the pollutants that contribute to poor air quality are anticipated in future. As these emission reductions occur, the role of nitrate aerosol and secondary chemistry is expected to become more important in the formation of haze. However, their representation in climate models is currently limited due to computational constraints.

Recent work on UKCA, the UK community's model for chemistry and aerosol interactions, has implemented a suitable scheme for air quality applications, but this is significantly larger and more complex than the current scheme used within the Earth System model. To enable such simulations, new computational techniques which can exploit highly parallel compute devices such as GPUs are required, as they have higher computational performance per watt than traditional computer processors. They require novel and parallel, programming methods to exploit. Moreover, the proliferation of processor architectures means different methods and coding patterns are required for each.

This project addresses two research questions. The first is what advanced computational science techniques can be applied to the UKCA science code to make the model portable to multiple computer architectures and, critically, performant on those architectures? This then provides the methodology to address the second question: what is the effect of aerosol reductions on projections of near-future Indian air quality, and how do these projections differ in simulations with nitrate aerosol coupled with improved chemistry, compared to projections with the standard scheme?

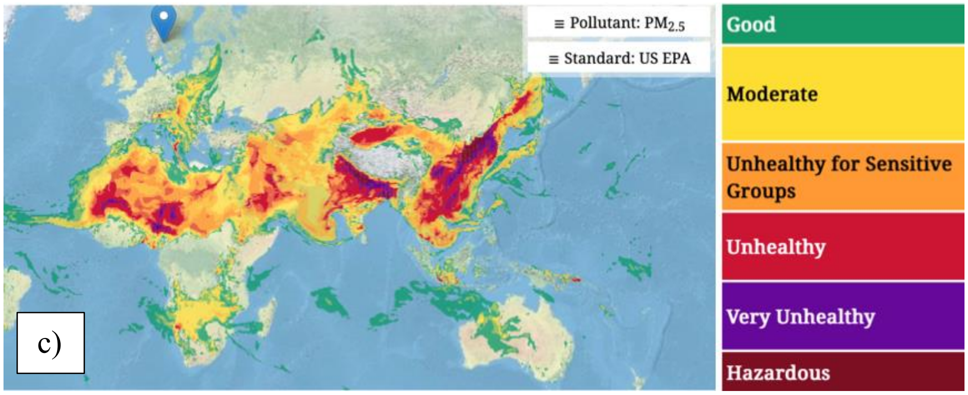

Figure: a) The Jasmin Supercomputer, which will be used in the project; b) Smog in Delhi, the city with the worst air quality in the world (taken from BBC and credited Getty images); and c) an air quality forecast for 16/10/22 from the US National Park Service, showing poor air quality across northern India.

To address these questions the student will work with a standalone version of the chemistry model known as the box model to explore programming and algorithmic optimisations for GPU processor architectures. The student will be supported with training for programming GPUs. The Jasmin Supercomputer (see figure) is an example development platform. The computational improvements can then be employed using the Next Generation Modelling System (LFRic) from the Met Office. A series of simulation experiments can then be run to quantify the impact of different air quality policies on Indian air pollution. The computational developments, model runs and the analysis of the resulting data will form the content of the thesis. This gives the student the opportunity to test the performance of the enhanced chemistry and address a key outstanding question in climate science policy and mitigation.

The computational developments, model runs, and the analysis of the resulting data will form the content of the thesis. This project is an opportunity for the student to become an expert both in scientific model development and an important scientific topic. These skills combined are highly relevant and are seen as desirable by modelling centres, such the Met Office and NCAS. The research undertaken is relevant to both scientific computing and atmospheric science, both of which are publishable.

Training opportunities:
The student will be offered courses in parallel programming and software engineering in the computer science department and NCAS courses in atmospheric science, scientific computing and the UKCA model. The project offers an opportunity for the student to work at the Met Office where they will experience a highly interdisciplinary, non-academic research environment, including training in using and developing the LFRic model. SCENARIO provides the student with opportunities to develop their presentation skills, and to network at conferences, with further opportunities for discussion of their work provided by the multi-institutional multi-disciplinary supervisory team.

Student profile:
This project would suit a student with a background in computer science, physical or mathematical sciences. The student must have strong analytical skills. During the project the student will be expected to develop the necessary computer programming and climate data analysis skills. Some previous programming experience would be beneficial.

References:

https://research.reading.ac.uk/scenario/
https://www.ukca.ac.uk/wiki/index.php/UKCA
https://www.metoffice.gov.uk/research/approach/modelling-systems/next-gen-modelling-systems