Using data science with multi-fluid modelling of atmospheric convection

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The fusion of high-resolution modelling and data science is the future of weather and climate research. This is reflected in the new generation of supercomputers which combine general-purpose computing with artificial intelligence. This project takes a highly innovative step, harnessing machine learning to improve the representation of clouds and atmospheric convection in weather and climate models.

Can data science be used to improve the representation of clouds and rain in climate models?

The global atmosphere is fueled by convection; rising hot air creates clouds, rainfall, extreme weather and drives the global atmospheric circulation. However the representation of convection is one of the weakest aspects of climate models (Tomassini, 2020). The lead supervisor has recently proposed a new approach for representing atmospheric convection; multi-fluid modelling (Weller et al, 2020), with a separate fluid partition for representing the convecting part of the flow, potentially enabling convection to be represented accurately with a fraction of the computing cost of fully resolving the convection. However the full form of the multi-fluid equations for representing convection is not known; terms in the equations are needed for transferring fluid between the partitions, representing pressure differences between the partitions and representing sub-grid-scale turbulence.

A wealth of data from high resolution simulations of convection is available from previous projects. This data will be used to find the size of the unknown terms of the multi-fluid equations. However we need to find the form as well as the size of the unknown terms so that they can be predicted using low-resolution, energy efficient models. This is where machine learning comes in. A library of resolved variables will be created on which the unknown terms may depend. The data science can then be used to discover which combination of resolved variables best reproduces the unknown, sub-grid terms. This will provide physical insight into how the coherent structures of convection act and to what extent that interaction can be universally represented.

The terms identified by the data science techniques will be implemented into an existing three-dimensional multi-fluid model of the atmosphere and evaluated by simulating various convection test cases. The project is timely because of the wealth of high-resolution data now available and the maturity of multi-fluid modelling which has shown promise in simplified settings and now needs to be confronted with high resolution data.

Training opportunities:
The student will spend time working with Lorenzo Tomassini at the Met Office using the new supercomputer with artificial intelligence capabilities, analysing high resolution convection data and evaluating the new Met Office model of atmospheric convection.

Student profile:
The project would be suitable for a student with a degree in physics, mathematics, engineering, or a closely related subject with a high mathematical content, programming experience and a desire to write good code with supervision and support. This project is also about low resolution, energy efficient computing so would suit a student with a desire to reduce the carbon footprint of weather and climate prediction.

Funding particulars:
This project has co-sponsorship from the UK Met Office in the form of a CASE award. This will supply an additional £1000 per annum to the student for three years and also funds travel and subsistence for the student to undertake a 3-month placement at the Met Office.

References:

H. Weller, W. McIntyre, and D. Shipley. J. Advances in Modeling Earth Systems, 12(8), 2020.

L. Tomassini, The interaction between moist convection and the atmospheric circulation in the tropics, Bull. Am. Meteorol. Soc., 101, 2020.

https://research.reading.ac.uk/scenario/