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Natural Environment Research Council

2024_59_Physics_HB: Capturing the spectral fingerprints of errors in weather and climate models

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The balance between net incoming solar radiation ("shortwave") and outgoing thermal-infrared ("longwave") radiation at the top of the Earth's atmosphere fundamentally drives our weather and climate. Broadband, spectrally integrated, measurements of the solar radiation reflected by the Earth and outgoing longwave radiation (OLR) emitted by the Earth have been made by a variety of satellite sensors for almost four decades. These observations are often used to assess the performance of numerical weather prediction and climate models. However, because these broadband measurements integrate all the energy across the shortwave or longwave spectrum, compensation effects may mask deficiencies in the representation of processes that are key for predictive capability.

Conversely, spectrally resolved measurements of the outgoing radiation can be used to identify and monitor the effects of many different processes as well as providing a constraint on underlying assumptions within a specific model. Resolved measurements of OLR now span more than two decades. Several future missions (e.g. FORUM and TRUTHS) promise to deliver enhanced spectral coverage and measurement accuracy across both the long and shortwave spectrum. In parallel, recent improvements in the treatment of radiation within the ECMWF model have opened up the potential to directly output spectral information. Together, these developments make this an ideal time for this PhD project.

Particular known biases and uncertainties in the ECMWF model are related to the excessive leakage of water vapour from the troposphere to the polar lower stratosphere, uncertain water vapour "continuum" absorption, surface emissivity and ice-cloud microphysics, all of which have strong spectral fingerprints. We envisage that the student will first work to add the capability to output spectral radiation from the model. With this capacity, the project will then deliver bespoke model output that will be compared to the available measurements to identify biases in spectral radiation and track how they evolve as the forecast progresses away from initial conditions, both in the short-term and in longer-term climate-type runs. Modifications will be made to physical processes in the model in order to improve the fit to the spectral observations. In this way the project will deliver novel, and very necessary insight into exactly how spectral measurements can be exploited to improve models and potentially their predictive skill over weather and climate timescales. It will also give confidence that we have validated modelling tools that are ready to use as and when the new satellite missions are launched.

Relevant references:

Fox and Green, 2020, Traceable Radiometry Underpinning Terrestrial- and Helio Studies (TRUTHS): An Element of a Space-Based Climate and Calibration Observatory, https://doi.org/10.3390/rs12152400.

Palchetti et al., 2021, FORUM: unique far-infrared satellite observations to better understand how Earth radiates energy to space, https://doi.org/10.1175/BAMS-D-19-0322.1.

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