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Acceleration of a ray tracing parameterization of gravity wave momentum transport

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The parameterization of gravity wave momentum transport remains an active area of research in atmospheric model development. Although small relative to the synoptic flow, un- and under-resolved gravity waves can systematically modify the propagation and breaking of Rossby waves, thereby playing a significant role in the planetary-scale circulation. Parameterizations seek to faithfully represent these waves and their effects at minimal computational cost. Ray tracing is a promising method for modeling momentum transport associated with atmospheric gravity waves, allowing one to capture the propagation and dissipation of gravity wave packets. However, ray tracing parameterizations, such as the Multiscale Gravity Wave Model (MS-GWaM), have seen only limited adoption, in large part due to their computational intensity. Operational use of such parameterizations will remain challenging unless their efficiency can be increased by an order of magnitude or more.

Both the convergence and the runtime of ray tracing models are governed by the maximum number of Lagrangian rays permitted to exist at once and their resolution in wavenumber-height phase space. We investigate the use of coarse graining, intermittency, and machine learning to achieve comparable accuracy with dramatically fewer rays. We implement an idealized, one-dimensional version of the MS-GWaM ray tracer that models the interactions between internal gravity waves and a height- and time-varying mean flow. This model allows us to carefully analyze the errors present in resource-constrained integrations. Near the wave source, error is attributable to decreased phase-space resolution; we improve performance in this regime with a neural network trained to respect conservation properties of the system. Further aloft, we find that the error is driven by premature pruning of ray volumes and can be mitigated by introducing intermittency to the source. We explore these techniques and their marriage across a variety of test cases ranging from idealistic to GCM-informed.

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