Cumulant expansion closures for geophysical turbulence: From planetary scales to boundary layers

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Turbulence closures based on truncated cumulant expansions usually do not perform well in homogeneous turbulence problems, because the first moments are not of interest. However, geophysical turbulence problems are generally inhomogeneous, and first moments (e.g., mean temperatures, winds, and precipitation) are of primary interest. In addition, geophysical turbulence is often weak (with prominent waves and hence strong non-locality in space), rendering cumulant expansion closures that capture spatial correlations promising. Here I give an overview of cumulant expansion closures at second order (CE2), applied to geophysical turbulence from the scales of planetary circulations to boundary layers. Gross features of planetary circulations can be captured in CE2 closures, but there are also notable failures, in particular in representing turbulent momentum fluxes, for which critical layer dynamics not captured at CE2 are crucial. For boundary layers and clouds, cumulant expansion closures represent a fundamentally new approach of approaching the closure problem, one that now, with sufficient computational power, may lead to much better subgrid-scale closures than those currently employed in climate models.