Geophysical Turbulence Program Seminar

National Center for Atmospheric Research

Regularization Subgrid Modeling for Turbulence

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Abstract:

As the implementation of numerical modeling of geophysical and astrophysical flows exceeds technological limits and since truncation of the omitted scales removes important physics, a closure (e.g., subgrid (subfilter) modeling) is required. This work examines the use of regularizations as subgrid models for turbulent flows. Two related goals are their application (to extend what can be achieved with numerical modeling) and to gain understanding of turbulence (how regularizations alter the flow, which properties they retain). Four regularization models are compared to direct numerical simulations (DNS); exact subfilter scalings are derived and subfilter scale properties are explored numerically. Particular attention is given to intermittency, an essential feature of turbulence and a departure from self-similarity.

The Lagrangian-averaged magnetohydrodynamic alpha (LAMHD-alpha) model is applied to magnetofluids. The Lagrangian-averaged Navier-Stokes alpha (LANS-alpha) model and the Leray-alpha and Clark-alpha models (truncations of the subfilter-scale stress of LANS-alpha) are applied to nonconducting flows. Clark-alpha is associated with the first term of a Taylor expansion of the subfilter-scale stress. Leray-alpha and LANS-alpha represent advection by a smoothed velocity in an Eulerian and a Lagrangian sense, respectively.

Both Lagrangian-averaged models are found to reproduce the intermittency properties, such as the cancellation exponent, of the DNS. Exact scaling laws, analogous to the Kármán-Howarth equation, are derived for Leray-alpha and Clark-alpha. Leray-alpha results in an excessive reduction of the nonlinearity of the flow. Clark-alpha reproduces the large-scale energy spectrum of the DNS but exhibits increased intermittency at subfilter scales. This effect is reduced in LANS-alpha, likely, due to its conservation of circulation. This conservation results from Taylor's frozen-in turbulence hypothesis in LANS-alpha's derivation which also leads to the presence of "rigid bodies" (no internal degrees of freedom (dof) nor contributions to the energy cascade) at subfilter scales. Consequently, the energy spectrum scales as the wavenumber at subfilter scales.

We identify the shortcomings and promising features of regularizations as subgrid models of turbulence. They reproduce high-order statistics of turbulence, but the reduction in dof is rather modest. No model preserves best all properties of the flow and further studies are necessary, e.g., through coupling to Large Eddy Simulations.

When:

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Where:

Mesa Laboratory
Chapman Room

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