Slope-limiting Diffusion in Simulations of Convection and Thermal Plumes

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Compressible Spherical Segment (CSS) Code

- Solves primitive compressible MHD equations using:
 - 3rd or 4th order TVD Runge-Kutta for time evolution
 - 4th or 6th order modified compact finite differences for spatial derivatives [Lele (1992)]





captured in CSS Density stratification leads to expanding spatial scales with depth Coalescing downflows begin to feel global-scale effects (rotation and geometry)

Multi-scale near-surface flows

Interactions between the imposed global-scale flows and turbulent downflows become increasingly evident

Q: How might the nature of SLD influence the dynamics of this convection?

Slope-limiting Diffusion

- How does it fit into the overall picture of SGS/LES methods?
 - Slope-limiting
 Filtering of high wavenumbers

$$(\nu = 0) \neq \lim_{\nu \to 0} NS$$

Flow-dependent diffusion coefficient
 SGS Model of diffusion, enhanced where flows are fast

This is foremost a numerical stabilization procedure



Q1 -- How does SLD behave as a diffusion operator?



Q2 -- Can typical fluid prognostics and diagnostics be controlled or deduced?

Does the naïve approach sufficiently control Pr?



Q2 -- Can typical fluid prognostics and diagnostics be controlled or deduced?

How might we improve it's agreement?



Q3 – How much lower is the apparent diffusion?

How much lower is the diffusion?



16 times less resolution!

Q4 – Can SLD reproduce or mimic fluid instabilities

Thermal plumes (Pinch & Sinuous instabilities)

Which is Laplacian?

MRI (Does it match linear growth rates?)

Q5 -- Can it also produce consistent boundary layers? Q6 – Is there sufficient entrainment and detrainment? *How does this depend upon the SLD "Pr"?*

Slope-limiting Diffusion

Q1 -- How does SLD behave as a diffusion operator?

+ Local operator spectrally non-local

+ Implications for large-scale dynamos, instabilities, and cascades?

+ Could it excite instabilities that otherwise might not be present?

Q2 -- Can typical fluid prognostics and diagnostics be controlled or deduced?

+ Does the naïve approach sufficiently control Pr?

+ How much lower is the diffusion?

Slope-limiting Diffusion

- Q4 Is there sufficient entrainment and detrainment?
- + How does this depend upon the SLD "Pr"?
- Q5 -- Can SLD reproduce or mimic fluid instabilities?
- + Thermal plumes (Pinch & Sinuous instabilities)
- + MRI (Does it match linear growth rates?)
- Q6 -- Can it also produce consistent boundary layers?