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Numerical evaluation of the validity domain of Lorenz equations as a model for natural convection in porous media

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Darcy flow in a two dimensional rectangular domain heated at the bottom and cooled at the top with perfectly insulated sidewalls is the topic of interest for this research. For Rayleigh numbers less than the critical value, Ra_{cr}, any disturbances will decay to a motionless solution and heat transfer will occur via conduction only. Above Ra_{cr}, natural convection develops in the domain. At some second critical Rayleigh number, Ra_t, the steady convection cells lose stability and the solution transitions to a weakly turbulent state. An approximate analytical solution was derived, using weak nonlinear analysis, by asymptotically expanding the solution about Ra_{cr}, resulting in a nonlinear system of equations that is equivalent to the Lorenz system. This solution is able to more accurately predict the transition from steady convection to weak turbulence because the initial conditions are taken into account in the analysis. However, the approximate analytical solution is only valid for Rayleigh numbers sufficiently close to Ra_{cr}. This research investigated the validity domain of the Lorenz system as a model for natural convection in porous media. The temperature and velocity fields given by the Lorenz system were compared to a numerical solution for the temperature and velocity fields for increasing Rayleigh numbers. Near $Ra = 100$, the number of convection cells predicted by the numerical solution increase from two to three resulting in a significant increase in difference between the Lorenz system and the numerical solution. To provide a comparison between the Lorenz solution and the numerical solution that is global in scale relative to the problem domain, the Nusselt numbers resulting from each solution are compared to each other and also to experimental data.

References

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