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Plain Language Summary: A formulation of a three-dimensional spectral model based on the primitive equations is proposed. In this formulation, the Legendre polynomial expansion is used for the vertical discretization. By performing several calculations with different vertical degrees of freedom, a characteristic property of the spectral method is observed in which the error of the numerical solution decreases rapidly when the number of vertical degrees of freedom is increased.

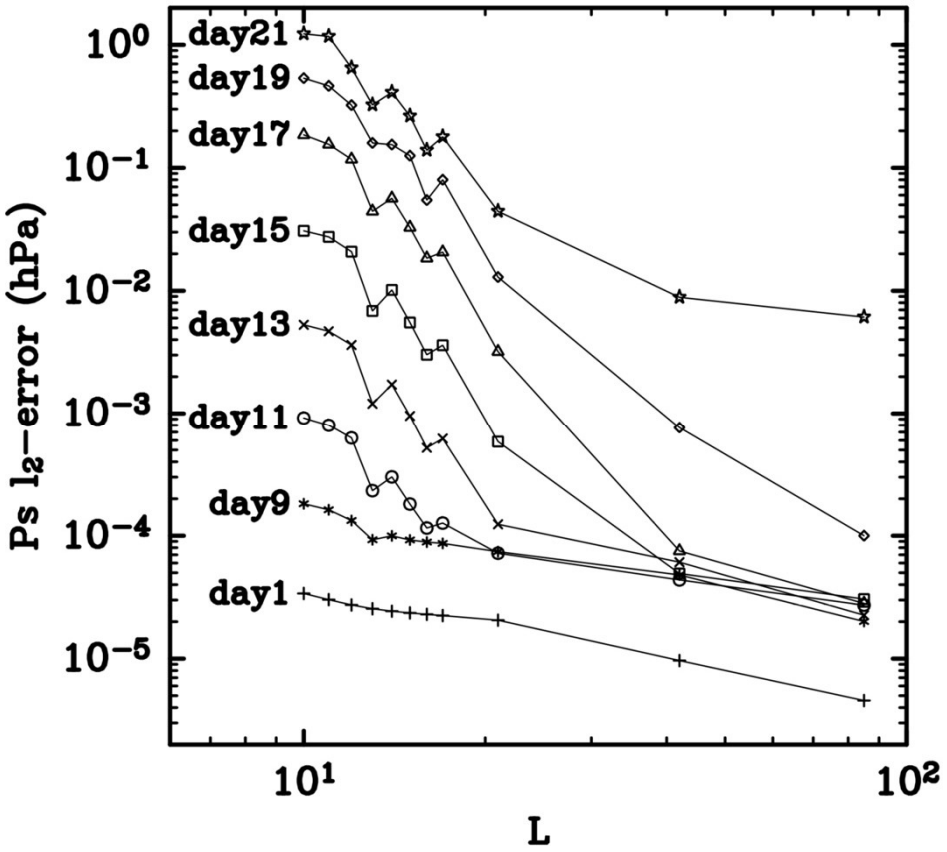

Figure 1. The dependence of l_2 error of the surface pressure field on the vertical truncation wavenumber L in the time-evolutions of baroclinic disturbances. The horizontal places of the markers indicate the values of the vertical truncation wavenumber L used in the time-integrations (L = 10, 11, 12, 13, 14, 15, 16, 17, 21, 42, and 85). The corresponding number of the vertical grids, K, is K = 16, 18, 20, 20, 22, 24, 26, 26, 32, 64, and 128, respectively. The number of days is indicated at the left end of the line connecting the markers. The result at L = 170 (K = 256) is taken as the true value here, and we define the difference from it as the error. The time-integrations are done with the horizontal truncation wavenumber of T85 (256 × 128 grids) and the time step of 150 s.

• Semi-implicit time integration can be efficiently done under this formulation.
• This implementation of the primitive equations can give accurate numerical solutions with a relatively small degrees of freedom in the vertical discretization.
• An alternative to the sponge layer can be devised to suppress the reflected waves under this formulation.