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数值差分格式及格点设置对土壤温度模拟结果的影响

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Effects of difference and grid scheme in soil temperature simulation

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摘要 土壤温度是反映气候系统和生态系统能量循环的重要地球物理学参量,土壤温度的模拟精度直接影响着气候系统模式以及陆面物理过程模式的模拟结果.为了提高模式对土壤温度的模拟能力,本文利用土壤热扩散方程的傅里叶解析解定量研究了差分方案、格点设置以及时间步长对土壤温度模拟结果的影响;提出了一种优化的格点设置方案,并利用巴丹吉林沙漠观测数据检验了该方案的性能.研究结果表明:三种差分方案中,显式方案的模拟误差最小,Crank-Nicolson方案其次,隐式方案的模拟误差最大;每一种格点设置方案均存在一个使模拟结果误差最小的最优化时间步长;常用格点设置方案的最优化时间步长为5358 s,最小标准差为0.156 K,优化方案的最优化时间步长为1694 s,最小标准差为0.0465 K;取时间步长为1800 s时,采用常用格点设置方案,巴丹吉林沙漠10 cm深度土壤温度模拟结果的标准差为1.61 K,而采用优化方案,模拟结果的标准差降至0.21 K,改进效果明显.

关键词 土壤温度模拟, 热扩散方程, 差分方案, 格点设置, 陆面过程

Abstract: Soil heat storage and transfer plays a key role in energy cycle of the earth system. In earth system model and land surface model it is especially important to accurately reproduce the observed diurnal cycle of soil temperature. In order to improve the performance of numerical models, we employed an analytic solution of the soil thermal diffuse equation to analyze the impact of discretization scheme, grid scheme and time step on the soil temperature simulation. We found the explicit discretization scheme is the most accurate scheme, Crank-Nicolson takes the second place, and the implicit scheme is the worst. Furthermore, on the basis of ordinary grid scheme, an optimal grid scheme was suggested, and both of them were applied in the simulation of Badanjaron Desert's soil temperature. The optimal time step for ordinary grid scheme is 5358 s, with which the standard deviation takes the minimum value as 0.156 K. By using optimal grid scheme, the minimum standard deviation error is 0.0465 K, while the optimal time step is 1694 s. Comparison of two simulated soil temperatures at a depth of 10 cm for a site in Badanjaron Desert shows that the standard deviation error drops to 0.21 K from 1.61 K by switching from ordinary grid scheme to optimal grid scheme.

Keywords Soil temperature simulation, Thermal diffuse equation, Difference scheme, Grid scheme, Land surface process

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