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# 大气$CO_2$浓度非均匀动态分布条件下的气候模拟

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## Climate simulation for dynamic heterogeneous distribution of atmospheric $CO_2$ concentration

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摘要 利用现有大气本底站的大气$CO_2$浓度观测信息,综合考虑不同经济区划与土地覆盖类型对应的$CO_2$浓度差异及其季节变化规律,构建模式区域内以月为单位的网格化大气$CO_2$浓度非均匀动态分布数据模型.由此数据模型驱动RegCM4-CLM3.5区域气候模式运行,对东亚区2000年3月—2009年2月之间的气候变化特征进行了模拟,进而对大气$CO_2$浓度非均匀动态分布可能引起的区域气候效应进行了初步研究.结果表明:目前气候模式中$CO_2$浓度的常态均匀分布假设可能将温室效应夸大了10%左右.对大气$CO_2$浓度非均匀动态分布影响气温变化的可能机制进行研究表明:$CO_2$的自身效应(改变大气透射率)并不是导致Exp2试验温度降低的主要原因.大气$CO_2$浓度的变化影响了大气与植物胞间$CO_2$分压差,陆地植被通过改变气孔阻力适应这种变化,气孔阻力的变化直接影响到植物与大气间水分的交换,这种作用一方面通过蒸发冷却改变环境温度,另一方面,蒸发水分改变了近地面层湿度,进而水汽扩散到空中影响低云的分布.冬季,植物处于非生长季,对大气$CO_2$浓度变化响应微弱,湿度和低云变化不明显;夏季,植物生长旺盛,由$CO_2$生理学强迫激发的云反馈效应强烈,其效果是使中低云趋于增加,进而减弱了到达对流层低层的太阳短波辐射,造成温室效应减弱.

关键词 大气$CO_2$浓度, 非均匀动态分布, 温室效应, 云反馈, $CO_2$生理学强迫

Abstract: Based on the baseline concentration data of atmospheric $CO_2$ observed from the GAW stations, considering the heterogeneous distributional characteristics of $CO_2$ concentration among different economic regions and land use types, this paper constitutes a dynamical heterogeneous atmospheric $CO_2$ concentration data set that varies monthly within a regional climate model domain around China. By running the RegCM4-CLM3.5 regional climate model with the dynamic heterogeneous $CO_2$ concentration data set, the climate change characteristics of the East Asia from March 2000 to February 2009 are simulated and the model outputs data are analyzed by comparison method. The possible mechanism that the dynamic heterogeneous $CO_2$ distribution causes different regional climate change is also studied. The simulation study shows that the greenhouse effect of $CO_2$ might have been aggrandized about 10% in the tranditional climate simulation due to the improper assumption of stable and homogenous atmospheric $CO_2$ concentration. Then the paper analyzes the possible mechanism of greenhouse effect reduction induced by the dynamic heterogeneous $CO_2$ concentration distribution. The analysis indicates that the greenhouse effect by $CO_2$ itself (always referred as changing atmospheric transmittivity) is not the main reason to deduct temperature in the Exp2. The variety of atmospheric $CO_2$ concentration influences on the $CO_2$ partial pressure between atomosphere and internal plant cell first, and then the land plants adjust to this change by altering their stomatal conductance, which affects the water evapotranspiration from plant leaf to atmosphere consequently. On the one hand, these effects affect environmental temperature through the

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evaporation cooling, on the other hand, the evaporated moisture alter the air humidity and influence the formation and amount of low cloud. In winter, most plants are under dormancy season, there are little response to the change of atmospheric $CO_2$ concentration, and then the change of the humidity and low cloud is unconspicuous. In summer, the most plants are under the vigorous growing period and there are more active biological actions that tranfer more water vapor into the atmosphere and then more cloud formatted due to this $CO_2$ physiological forcing effect. The increased low cloud resist the solar shortwave radiation from reaching the lower part of the atmosphere and cause temperature reduction, on the other hand, the radiative cooling effect from the top of the cloud can also cause lower temperature in the troposphere.

Keywords Atmospheric $CO_2$ concentration, Dynamic and heterogeneity, Greenhouse effect, Cloud feedback, $CO_2$ physiological forcing

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