论文类成果

Improving water quantity simulation & forecasting to solve the energy-water-food nexus issue by using heterogeneous computing accelerated global optimization method

【创新性】

基于 CPU 与 GPU 协同的异构并行大规模高性能计算加速方法与技术，在算法并行化理论、并行硬件优化配置和并行软件开发调优三方面进行了创新性研究并取得突破，大幅提升计算效率，实现了高效率、精准化、精细化、价廉物美的快速计算。以水文模型参数率定为例开展研究，计算速度提升高达 53 倍。成果体现了四“新”的特点：主要研发人员为新一代科研工作者，出生年代为八零后；文章为新成果，发表于 2018 年；研究成果为新技术，体现 GPU 高性能并行计算的发展方向；成果体现了新水平，发表在一区行业 TOP 期刊，影响因子高达 7.9，为高被引论文，受到国内外权威专家和权威 GPU 制造商高度认可。

【影响力】

该加速方法与技术应用前景广泛，可用于高时空分辨率大范围分布式水文水动力学模型计算加速、大尺度水文－气象耦合模型计算加速及各类数值计算问题的加速。文章发表在 JCR 分区一区期刊，影响因子 7.9，SCI 数据库认定为高被引论文。中国工程院院士、长江学者、千人计划特聘专家、国家自然科学基金杰出青年基金获得者等专家进行高度评价：该方法大幅提升了水文模型参数优选计算效率，该先进的参数优选算法提供了一种计算效率很高的求解方法。获全球最大最强并行计算芯片设计和生产商（英伟达公司）学术研究奖励。

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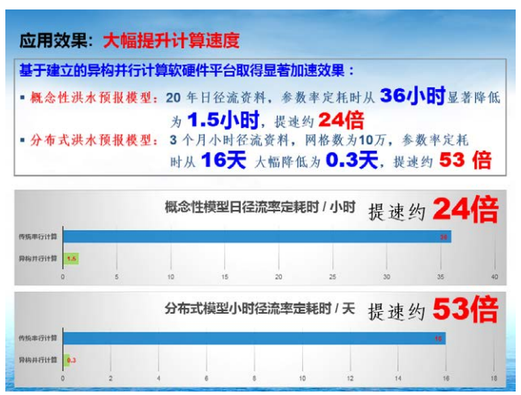
受奖单位：减灾中心

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Improving water quantity simulation & forecasting to solve the energy-water-food nexus issue by using heterogeneous computing accelerated global optimization method

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HIGHLIGHTS

- We proposed a novel parallel SCE-UA method
- We implemented the parallel SCE-UA on multi-core CPU and many-core GPU.
- The parallel SCE-UA can obtain global optimum much faster than original serial version

ARTICLE INFO

ABSTRACT

With continuous population increase and economic growth, challenges on securing sufficient energy, water, and food supplies are amplifying. Water plays the most important role in the energy-water-food (E-W-F) nexus issue such as energy supply (clean hydropower energy generation), water supply (drinking water), and food supply (agricultural irrigation water). Therefore, water quantity simulation & forecasting become an important issue in E-W-F nexus problem. Water quantity simulation & forecasting model, such as rainfall-runoff (RR) hydrological model has become a useful tool which can significantly improve efficiency of the hydropower energy generation, water supply management, and agricultural irrigation water utilization. The accuracy and reliability of the water quantity simulation & forecasting model are significantly affected by the model parameters. Therefore, demand of effective and fast model parameter optimization tool for solving the E-W-F nexus problem increases significantly. The shuffled complex evolution developed at University of Arizona (SCE-UA) has been recognized as an effective global model parameter optimization method for more than 20 years and is highly suited to solve the E-W-F nexus problem. However, the computational efficiency of the SCE-UA dramatically deteriorates when applied to complex E-W-F nexus problem. For the purpose of solving this conundrum, a fast parallel SCE-UA was proposed in this paper. The parallel SCE-UA was implemented on the novel heterogeneous computing hardware and software systems which were constituted by the Intel multi-core CPU, NVIDIA many-core GPU, and PGI Accelerator Visual Fortran (with OpenMP and CUDA). Performance comparisons between the parallel and serial SCE-UA were carried out based on two case studies, the Griewank benchmark function optimization and a real world DACRES RR hydrological model parameter optimization. Comparison results indicated that the parallel SCE-UA outperformed the serial one and has good application prospects for solving the water quantity simulation & forecasting model parameter calibration in the E-W-F nexus problem.

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【Innovation】

Based on the heterogeneous-parallel, large-scale and high-performance computing acceleration method and technology with CPU and GPU, this thesis conducts innovative research on algorithm parallel theory, optimal configuration of parallel hardware and development and optimization of parallel software and obtains breakthroughs, improving computing efficiency greatly and realizing efficient, precision, delicate and inexpensive and high-quality fast computing. It carries out research on hydrological model parameter calibration, and increases computing speed by 53 times. The achievement demonstrates four "new" characteristics: major research personnel are a new generation of researchers who are post-80s; the paper is a new achievement published in 2018; research findings are new technologies that embody the development direction of the high-performance parallel computing of GPU; and the achievement demonstrates the new level. It is published on top journal in Q1, with an impact factor of 7.9 as a highly-cited paper, and is highly recognized by authoritative experts and GPU manufacturers at home and abroad.

【Influence】

This acceleration method and technology has broad prospects of application as it is applicable to computing acceleration of hydrologic and hydrodynamic models with high temporal-spatial resolution and extensive distribution, large-scale hydrology-meteorology coupling models and various numerical computing problems. This paper is published on JCR Q1 journal, with an impact factor of 7.9, and is affirmed as a highly-cited paper in SCI. CAE academicians, Changjiang scholars, and distinguished experts of the Recruitment Program of Global Experts speak highly of it: this method improves the efficiency of parameter optimization computing for hydrologic models significantly, and the advanced parameter optimization algorithm provides an efficient solution. It receives the academic research award from the world's largest and most powerful parallel computing chip designer and manufacturer (NVIDIA).

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Li Jiren, Ding Liuqian, He Xiaoyan, Hong Yang, Zuo Depeng
Award-winning Unit : Research Center on Flood and Drought Disaster Reduction

IMPROVING WATER QUANTITY SIMULATION & FORECASTING TO SOLVE THE ENERGY-WATER-FOOD NEXUS ISSUE BY USING HETEROGENEOUS COMPUTING ACCELERATED GLOBAL OPTIMIZATION METHOD