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中文题名	水沙及水质数学模型中基于粒子滤波的数据同化研究
英文题名	Data Assimilation on Hydrodynamic Sediment Transport and Water Quality Model with Particle Filter
中文关键词	水动力模型,泥沙模型,水质模型,数据同化,粒子滤波
英文关键词	Hydrodynamic model,Sediment transport model,Water quality model,Data assimilation,Particle filter
中文文摘	水沙及水质数学模型是水利工程设计和管理中的重要工具。数学模型的优点在于可通过内在动力学规律模拟出研究对象的时空连续分布，且耗费的资源很低。传统数学模型通过改变边界条件等方式来模拟不同工况进行比选，在工程规划中效果良好，可称之为“规划模型”。但受模型结构、输入和参数等因素的误差影响，在实时预报计算中，“规划模型”的结果具有很大的不确定性，不能满足实时模拟预报的要求。随着物联网技术在水利行业中的应用，水情观测的实时精确感知能力大大增强，但水情观测站点无法覆盖所有的研究区域和时段，同时观测的成本很高。数据同化方法，可以将数学模型和观测两者的优点有机结合，通过将实时观测数据合理地融入到数学模型中，提升数学模型实时模拟预报的精度和可靠度，从而将数学模型由传统“规划模型”发展为当前物联网时代的“实时模型”。本文采用适用于非线性和非高斯模型的粒子滤波作为数据同化研究方法，将其分别应用于水动力、泥沙和水质（河流磷迁移和富营养化水华）数学模型中，构建粒子滤波同化模块，根据实时观测数据，对数学模型进行同步校正和不确定性估计。在水动力模型同化研究方面，采用一维非恒定流模型作为河道洪水传播模型，以实时水文观测信息作为观测数据，对水位和流量进行优化更新，同时对河段糙率系数进行动态校正。所构建的河道洪水实时概率预报模型应用于长江三峡区间河段，可以有效地提升计算河段水位、流量预报的精度和可靠度。在泥沙模型同化研究方面，采用一维非平衡悬沙输移模型作为研究模型，以实时含沙量观测信息作为观测数据，对含沙量进行优化更新，同时对恢复饱和系数、挟沙力公式系数及指数进行动态校正。所构建的泥沙模型同化系统应用于黄河调水调沙过程计算中，可以有效优化含沙量，同时反演出模型参数随水沙条件的动态变化过程。在河流磷迁移模型同化研究方面，选取河流水动力-泥沙-磷迁移数学模型为研究模型，以实测磷含量为观测数据，优化各相磷含量模拟结果，同时对模型时变参数进行动态校正。所构建的河流磷迁移同化系统应用于长江三峡区间河段，可以有效提升各相磷浓度过程的模拟预报精度。在水华动力模型同化研究方面，选取 EFDC 模型作为水华动力模型，以实测叶绿素 a 浓度为观测数据，同步更新和校正水质状态变量和模型参数。所构建的水华实时概率预报系统应用于香溪河库湾，可有效地提升水华预报的精度和可靠度，同时反演出时变参数的变化过程。
外文文摘	Observation analysis and mathematical model are two basic research methods in water science. The advantage of observation analysis is that the accuracy and reliability of the observed data are high, but the disadvantage is that the observed data are limited in time and space. The advantage of the mathematical model is that the temporal and spatial distribution of the model state variables can be simulated by the laws of internal dynamics, but the disadvantage is that the model result is of high uncertainty. The data assimilation technique can combine the advantages of mathematical model and observation analysis. By integrating the observations into the mathematical model, the model state variables are updated and the parameters are dynamically corrected. At the same time, the uncertainty associated with the model is estimated to improve the accuracy and reliability of model forecasting. In this paper, Particle Filter (PF) is applied to nonlinear and non-Gaussian models as data assimilation method. PF is applied to the hydrodynamic model, sediment transport model and water quality model (river phosphorus migration model and algal bloom dynamic model), respectively. In the assimilation of the hydrodynamic model, the one-dimensional unsteady flow model is adopted as the model of river channel flood propagation, and the real-time hydrological observations are assimilated to update the water level and discharge and correct the Manning roughness coefficient. The real-time probabilistic channel flood forecasting model with PF is tested with synthetic and real-

	world experiments in the upstream river reach of Three Gorges Dam (TGD) on the Yangtze River, which shows an accurate and reliable preformance. In the assimilation of the sediment transport model, the one-dimensional non-equilibrium suspended sediment transport model is adopted to estimate the suspended sediment concentration (SSC), and the real-time SSC observation is assimilated to update the SSC and correct the saturation recovery coefficient, the coefficient and exponent in sediment carrying capacity formula. The developed SSC data assimilation system with PF is applied to the Yellow River water and sediment regulation process to evaluate its performance, which indicates that the accuracy and reliability of the SSC estimation is enhanced and the parameters are dynamically corrected effectively. In the assimilation of the river phosphorus migration model, the hydrodynamic-sediment-phosphorus model is adopted to estimate the phosphorus concentrations and the observed data of phosphorus concentration are assimilated to update the phosphorus concentrations and correct the model parameters. The developed data assimilation system of river phosphorus migration is applied to the Changjiang River segment from Cuntan to Three Gorges Dam to evaluate its performance of estimating phosphorus transport, which shows that the accuracy of estimation of phosphorus transport can be enhanced significantly due to the effect of assimilation. In the assimilation of the algal bloom dynamic model, Environmental Fluid Dynamics Code (EFDC) model is adopted to simulate the algal bloom event and the observed chlorophyll a concentration is assimilated to update the water quality state variables and correct the model time-varying parameters. The developed data assimilation system of algal bloom dynamics with PF is applied to the algal bloom events in Xiangxi tributary embayment of TGD reservoir to evaluate its performance of predicting algal bloom. The results show that the new model can improve the accuracy and reliability of the algal bloom prediction effectively and correct the time-varying parameters dynamically.
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