A MULTI-SOURCES DATA ASSIMILATION SYSTEM FOR CATCHMENT SCALE RESEARCH

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ABSTRACT

A multi-sources data assimilation system has been developed for the catchment scale land water and energy cycle researches. The land surface model, microwave radiative transfer model and ensemble Kalman filter have been coupled in this system, the high performance computing was also considered. This system is being used in the data assimilation of soil moisture, soil temperature, microwave brightness temperature and snow water equivalent at catchment scale.

***Index Terms*—** Data assimilation, Remote sensing, Land surface model

1. INTRODUCTION

Remote sensing provides more and more valuable observation data for the catchment scale researches of hydrological and land surface processes [1-3]. In addition to the remote sensing measurements, we also can get large amount observation data from the ground based instruments. However, the numerical models still are the main research tools in these study fields [4]. The advantages of observation are their representation of the truth, but with limited spatial and temporal coverage and resolution. On the other hand, the spatial temporal continuous states can be simulated by the numerical models in a cheap way, but with lower quality because of the uncertainties contained in the input data and model physics. Therefore land data assimilation has become the popular method to fuse the high quality observation data and the numerical model results to obtain the improved water and energy states for researches [5, 6].

In recent years, several land data assimilation systems have been developed, such as Land Information System (LIS) [7], Canadian Land Data Assimilation System (CaLDAS) [8], European Land Data Assimilation System (ELDAS) [9] and Chinese Land Data Assimilation System (CLDAS) [10]. Due to the software availability or scalability, it is not easy to apply these systems for the multi-source observations assimilation research at the catchment scale. The multi-source observations that we will use include: soil moisture related observations from passive microwave sensors of Advanced Microwave Scanning Radiometer for EOS (AMSR-E) [11], Soil Moisture and Ocean Salinity (SMOS) [12], Soil Moisture Active/Passive (SMAP) [1], airborne microwave radiometer measurement, COsmic-ray and wireless network; active microwave sensors of Advanced Scatterometer (ASCAT) [13], Advanced Synthetic Aperture Radar (ASAR) [14], Phased Array type L-band Synthetic Aperture Radar (PALSAR); land surface temperature from Moderate-resolution Imaging Spectroradiometer (MODIS) [15] and soil temperature from wireless network; snow cover fraction from MODIS ; snow water equivalent ; snow depth from COsmic-ray ; water storage variations from Gravity Recovery and Climate Experiment (GRACE) and ground based water table measurement. Some of these measurements are the direct radiance data such as the microwave brightness temperature and we need to couple the radiative transfer model to do the data assimilation.

2. SCOPE OF NEW SYSTEM

None of the previous developed system can handle these multi-sources data together. Therefore, we have developed the High resolution land Data Assimilation System (HDAS) to make use of these multi-source observations at the catchment scale in a land data assimilation framework for improved estimation of soil moisture, soil temperature, evapotranspiration, snow and streamflow on a 1 km grid with a temporal resolution of 1 hour. HDAS was developed in Python and C++ programming language and the time manager of Python was used to control the HDAS flow.

The design of this new system covers the following aspects:

[1] Realistic watershed modeling. This new system will simulate the watershed hydrology (surface water and underground water), various land surface variables, driven by atmospheric forcing data (e.g., precipitation, radiation, wind speed, temperature, humidity) from various sources.

[2] Efficient data management. This high-resolution simulation and observation systems will produce huge

data, and the new system will retrieve, store, interpolate, post-processing and backup of the input and output data efficiently. The proposed software framework should include various components that facilitate the data management.

[3] Watershed observation processing and management. To provide the capabilities of downscaling, upscaling and quality control of the in-situ observation and the remote sensing data.

[4] Data assimilation and high performance computing. There will be a fast and more general, robust, adaptive and high physically-constrained data assimilation algorithm module. The proposed system should be a high dimensional data assimilation system intrinsically, it will perform high-performance, parallel computing for near real-time high-resolution land surface modeling research and operations.

[5] Interoperability. The new system could interoperate with internal components and the external system such as the Decision Support System. The unified data standards will be designed and implemented.

3. DEVELOPMENT OF NEW SYSTEM

Each module of the HDAS is designed separately and the external module can be easily integrated. The features of HDAS are as follows: evaluate different data assimilation algorithms, evaluate the strategies and impacts of the multi-source observations assimilation, the new version of model can be adapted with little modification to keep up to date and the high performance computation. The design goals of HDAS are off-line, high-resolution (up to 1km), catchment scale data assimilation system executed on highly parallel computing platforms, with well-defined standard conforming interfaces and data structures to interface and inter-operate with other Earth system models.

The execution of HDAS starts with reading in the user specifications in a control file. The user is responsible to choose the model domain, the model operator, the type of forcing data and observations data sources, how to read and write of restart files, system output specifications. HDAS applies spatial-temporal interpolation to convert the forcing data to the appropriate resolution required by the model. Since the forcing data is read in at certain regular intervals, HDAS also temporally interpolates time average or instantaneous data to that needed by the model at the current time step. The memory is dynamically allocated to the input and output variables. The intermediate information is stored in arrays, and output and restart files are written at the specified output frequency.

HDAS contains eight key components:

[1] Assimilation methodologies: from the direct insertion, the optimal interpolation, the variational method, the ensemble Kalman filter to the particle filter were implemented.

[2] Parameters and forcing data perturbation: different perturbation methods can be used in the ensemble generation of model parameters and atmospheric forcing data, such as additive noise and multiplicative noise.

[3] Sensitivity analysis: to identify the sensitive model parameters and model initial states for model calibration and assimilation.

[4] Model operator: the Community Land Model CLM and NOAH were chosen because of their full capabilities in modeling of the land water and the energy cycles.

[5] Observation operator: multi-source in situ observations, remote sensing observations and several microwave radiative transfer models were integrated.

[6] Parallel computing: two different parallel approaches were implemented to meet the challenge of the high performance computation because of the detailed model spatial delineation.

[7] Input and output: the NetCDF file format was used to manage all the input and output data efficiently.

[8] Visualization: to present the scientific data in different plot manners (1D, 2D or 3D).

The system structure is shown in Fig 1.

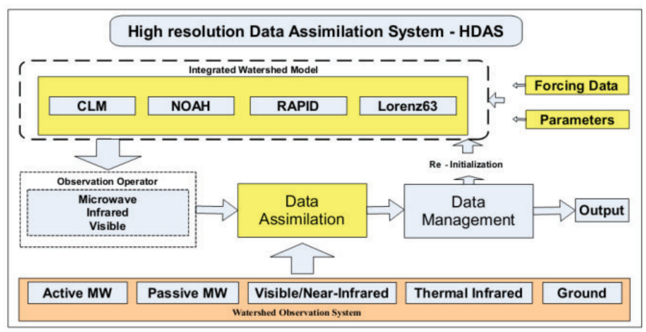

Figure 1. System Structure of HDAS

4. SUMMARY

One of the study objective in the watershed science is to fuse multi-sources remote sensing and ground based observation data and implement the real time prediction of the hydrological and ecological processes at the catchment scale. The hydrologic data assimilation system is the core to integrate all the measurement data. How to implement the system efficiently and how to make use of the products sufficiently in this system are the key points in the system development. We have met many challenges in developing the model operator, collecting data sets, optimizing the parameters, validating the observation operator and developing the data assimilation algorithms.

This system is being used in the data assimilation of the soil moisture, the soil temperature, the microwave brightness temperature and the snow water equivalent. The success of multi-sources data assimilation could server as an informative tool to improve the understanding of evolution of hydrological and ecological systems, and to support the sustainable water resources development in river basins.

5. ACKNOWLEGEMENT

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