Hydrology

H11A MCC: 3022 Monday 0800h

Observations and Modeling of Land Surface Hydrological Processes I *(joint with A, B, C)*

Presiding: **V Lakshmi,** University of South Carolina**; A Cahill,** Texas A&M University

H11A-01 0800h

Representation of Water Table Dynamics In a Land Surface Parameterization Scheme

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A recent regional-scale water balance analysis has indicated that the groundwater storage and groundwater runoff are significant terms in monthly and annual water balance for areas with a shallow water table. However, most of the current land surface parameterization schemes used with atmospheric models lack any representation of regional groundwater aquifers. This study attempts to address this deficiency. To incorporate water table dynamics into a land surface scheme (LSX), a lumped groundwater model (GW) is developed to represent the regional unconfined aquifer as a nonlinear reservoir, in which the aquifer simultaneously receives the recharge from the overlying soils and discharges runoff into streams. The dependence of groundwater runoff on the water table depth (WTD), i.e., groundwater rating-curve, is parameterized empirically based on the observations in Illinois. The groundwater model is linked to the soil model in the LSX through groundwater recharge flux. The total thickness of the unsaturated zone varies in response to the water table fluctuations, thereby interactively couples the aquifer model with the soil model. The representation of the sub-grid variability of water table depths (WTD) in the coupled model LSXGW is also attempted in this study. A statistical-dynamical (SD) approach is used to account for the effects of the unresolved sub-grid variability of WTD in the grid-scale groundwater runoff. The probability distribution function (PDF) of WTD is specified as a two-parameter Gamma distribution based on observations. The scale of this PDF is dynamic according to the varying grid-mean WTD at each time step. The shape parameter of the PDF describing the WTD is kept constant. The grid-scale groundwater rating-curve (i.e., aquifer storage-discharge relationship) is derived statistically by integrating a point groundwater runoff model with respect to the PDF of WTD. Next, a mosaic approach is utilized to account for the effects of sub-grid variability of WTD in the grid-scale groundwater recharge. According to the time-varying PDF, a grid-cell is categorized into different sub-grids based on WTD. The fraction describing each sub-grid can be determined from the WTD PDF; hence it varies with time. The grid-scale hydrologic fluxes are computed by averaging all the sub-grid fluxes weighted by their fractions. This new methodology combines the strengths of the SD approach and the mosaic approach. The developed model has been successfully tested in Illinois for an 11-year period (1984-1994). The results indicate that the simulated hydrologic variables (soil saturation and WTD) and fluxes (evaporation, runoff, and groundwater recharge) agree well with the observations in Illinois.

H11A-02 0815h

An Scheme for Application of Non-Uniform Grid Scales for Land Surface Modeling

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Vegetation, topographic, and hydrologic characteristics of the semi-arid Southwest U.S. suggest that, for those environments, it will be more meaningful to link the inherent heterogeneity and scale of the terrain properties and hydrological processes with the grid cell size of the numerical representation in land surface models, rather than pursue the traditional mosaic-type or effective aggregation approach currently used by the state of the art models. We present a multi-scale procedure for coupling a Land Surface Model (LSM) with atmospheric and subsurface processes that takes into account the different sensitivity of the models to the process scales and the availability of information for characterizing the parameter space. This Non-uniform Grid Scheme (NGS) utilizes hierarchical sub-grids with a degree of characterization that are nested within a grid-matched coarser grids preserving spatial location. Conservation of mass and momentum is maintained across the grids and aggregated fluxes are computed for the larger scale, which will be bi-directionally coupled to a fine-scale regional atmospheric model. A multiple resolution grid structure (500 m to 4 km) defined by the degree of land surface and sub-surface characteristics over the San Pedro River Basin in Arizona has been setup for the NCEP Noah LSM The model is driven in offline fashion with outputs from the NCAR Mesoscale Model (MM5). The results are compared to those from uniform grids with 1 and 4 km resolution. The influence of the parameter values is also assessed using the default values for semi-arid conditions (uniform for the entire domain) as a benchmark. The grid-dependent non-uniform parameterization is based on a multi-criteria approach using the newly developed MOSCEM optimization algorithm. The parameter values are derived from remote sensing, and values obtained from a combination of remote sensing and parameter optimization techniques.

H11A-03 0830h

Calibration of a Field-Scale and a Watershed-Scale SVAT Models for prairie wetland in Florida

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Improved quantification of the energy, moisture, and momentum fluxes at the land atmosphere interface is critical to studies in hydrology, meteorology, and biogeosciences. Soil Vegetation Atmosphere Transfer (SVAT) models have historically been used within the Atmospheric models to provide estimates of the land surface fluxes. SVAT models. They simulate 1-D energy and moisture transport at the land surface with one or more canopy layers and in the vadose-zone with multiple soil layers. They differ in the number of layers, the treatment of interception and in the methodologies used to estimate canopy ET, soil temperature, and soil moisture transport, depending on their intended applications. In this study, two SVAT models were calibrated for a highly variable convective atmospheric conditions and the atypical hydrogeology of the southeastern US. The two models, Common Land Model and the Land Surface Process model, are structurally different and were developed for different applications. This study examines the utility of increased sophistication in parameterization as it relates to differences in scale and their application in the southeastern US.

H11A-04 0845h

Calibration and application of a distributed land surface model for a semi-arid basin using remotely sensed data

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A meso-scale medium-resolution land surface model using the NCEP's NOAH code has been setup over the San Pedro basin in Arizona. The model is driven using the 50-year hydrologically balanced land surface data set developed at the University of Washington. To explore the sensitivity of simulation results and model performance to the introduction of remote sensing information, the observed forcings of precipitation and radiation in this dataset were replaced with the remotely sensed forcings of The University of Arizona's PERSIANN (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks) data and The University of Maryland's SRB (Surface Radiation Budget) data in stages. The model was calibrated for each of the vegetation types present in the basin to ground observations of the turbulent heat fluxes and ground temperatures using a multi-criteria calibration technique. The sensitivity of the model to vegetation classification and model resolution were also investigated.

H11A-05 0900h

Comparing the Performances of Common Land Model (CLM2) and Other Land Surface Schemes at Regional Scale (Oklahoma)

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The newly developed Common Land Model (CLM2) is one of the most complex land surface models among others and its performance needs to be evaluated with observations. The main goal of this study is to examine CLM2 in estimating soil moisture and runoff at regional scales. NASA Land Data Assimilation System (LDAS) is currently processing three land surface model runs (Mosaic, Variable Infiltration capacity model (VIC), and NOAH), except CLM2, over North America with 1/8-degree spatial resolution and hourly temporal resolution, which will be referenced in this study. The land surface models, CLM2 and VIC, are run and compared over the Oklahoma region with different rainfall data sets such as rain-gauge data, and Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) at 3 hourly and 1/8 degree resolutions. The Oklahoma region is chosen for this study because it has a well-defined observation network for water and energy exchanges including soil moisture contents, and relatively homogeneous topography. The IGBP vegetation classification and STASCO soil data are used to represent the land surface characteristics. This study is intended to extend the LDAS study, but is focusing on analyzing the effects of hydrological processes in current land surface models.

H11A-06 0915h

Evaluation of the Noah Land-surface Model for Semi-arid Sites in the Southwestern United States

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Numerous experiments have been carried out to facilitate the development and evaluation of land-surface models. Most of these comparison studies have been undertaken by the Project for the Intercomparison of Land-surface Processes (PILPS) under the sponsorship

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of the GEWEX Global Land-Atmosphere System Study (GLASS). However, few of these model evaluations have used long-term data sets (greater than one or two years) or have been carried out in semi-arid regions. Understanding the interaction of land surface processes with climate and its impact on the water cycle is crucial for predicting the availability of water resources in semi-arid regions. A recently proposed PILPS SanPedro-Sevilleta experiment is being undertaken in the southwestern U.S. using five semi-arid vegetation sites (including two from this study). A systematic analysis is undertaken based on the framework proposed for the PILPS experiment, testing some of the hypotheses for the calibration and cross-validation of land-surface schemes. This specific study analyzes the National Center for Environmental Prediction (NCEP) Noah land-surface model, one of several "community" or "multi-group" models that are evolving in land-surface studies. The MOCOM algorithm (a general purpose multi-criteria optimization algorithm that provides an estimate of the Pareto solution space) is linked with the Noah model to estimate parameters for two semi-arid biomes, a desert shrub and grassland, which have continuous meteorological and flux measurements over a four-year period. The model shows improved performance with calibrations (over default) and the model also does fairly well for sensible heat and ground temperature over the longer term. However, the increase in latent heat during short-term climatic events (the year-to-year monsoon and winter-time El Niño events) is not captured well in model simulations. The application of site-specific parameters at the two field sites does improve performance, but in the absence of calibration data, a proxy-basin set of parameters can be applied with only a slight decline in performance. Results from this analysis also show that several of the vegetation and soil parameters vary dependent on the length and period of calibration. Inadequate representation of these processes may result in large uncertainty in parameter estimates for semi-arid regions. The performance of models for long-term climate change scenarios is difficult to assess; however, the goal is that calibration and evaluation studies such as this and the PILPS SanPedro-Sevilleta experiment will lead to improved parameter estimates for use in regional and global long-term climate studies.

H11A-07 0930h

Evaluating the Influence of Spatial Processes and Information on Local Moisture-Outflow Relations: Characterizing the Scale of Interaction Using Soil Moisture and Precipitation Observations

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The issue of scale in land surface hydrology is often important. Components of root zone outflow (evapotranspiration, drainage, and runoff processes) are dependent on soil moisture. In some cases, this dependence can be reasonably described at the point scale (e.g. the Darcy and Richards equations). However, at larger scales, these interrelationships become increasingly complex and uncertain. Small-scale processes are one of many factors that may influence large-scale behavior. In modeling or monitoring frameworks, the presence of subgrid heterogeneity in landcover, soil parameters or forcings, non-linear flux behavior, and lateral flows or processes all can have substantial impacts on large scale behavior. A successful hydrologic model must balance the importance of these different factors with the need for computational efficiency and tractability. For example, one can conceive of two possible models for soil moisture - outflow relationships at a given location. A simpler model is an "independent columns" approach; i.e. outflow can be completely represented as a function of the soil moisture at that location only. However, in many cases this is a not valid model; lateral interactions and flow among sites may exist and influence the components of outflow at measured point, and/or large-scale phenomena may affect outflow in a way that is not captured by a locally independent model. In such cases, some sort of spatial aspect must be incorporated and addressed if moisture relations are to be successfully described, predicted or aggregated. Here we use a non-linear water balance parameterization, fit to observational precipitation and soil moisture data. The parameters are optimized by exploiting the equilibrium tendency of soil moisture time series. Spatial information is introduced through two parameters that modify the drainage and evaporation functions, and the importance of these parameters to the performance of the model is assessed by statistically evaluating their effect on the stationarity of the modeled soil moisture trace through entropy estimates; thereby determining whether lateral flows or processes are contributing to the observed behavior. An example with data from the Illinois Climate Network is presented.

H11A-08 0945h

Spatial Variability and Multiscale Errors in Assimilated Soil Moisture Fields

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Coupled land-atmosphere models are increasingly focused on using assimilated near-surface soil-moisture to improve the prediction of moisture and heat fluxes. Given that these models have a non-linear dependence on the soil-moisture state, it should be expected that errors in the observed soil-moisture will propagate through the system and influence the predictions of the model. Of particular concern is the situation when model predictions are made at scales that are different from that of the observation scales of the soil-moisture. In this case the transformation process of the soil-moisture from one scale to another introduces additional errors that will influence the prediction. The purpose of this study is to develop an understanding of the influence of multiscale observational errors in the soil-moisture on the prediction of surface fluxes. The following approach is adopted. We use the SGP'97 near-surface soil-moisture observation from ESTAR images at 0.8 km (resampled to 1 km). These observations are available for 16 days during the period June 18, 1997 to July 16, 1997. Using these we obtain estimates of the near-surface soil-moisture at several scales (1, 2, 4, 8, 16 and 32 km). This is accomplished through a multiscale estimation technique using a mean differenced fractal model [Kumar, 1999]. These multiscale near-surface observations are assimilated using extended Kalman filtering algorithm embedded in the NCAR-LSM (Land Surface Model). The assimilation is performed, once daily on the days when observations are available, at all scales for the entire study period to predict the soil-moisture profile and the surface energy fluxes. This allows us to address two key issues: (1) assessment of how the estimation error evolves with different moisture conditions as a function of scale, and (2) assessment of the spatial variability of assimilated fields at different scales. From the multiscaling results, we can observe that the estimation errors grow as the moisture increases in general at all the scales. Also there is a decrease in the estimation error as the scale increases. The assimilated fields show consistent spatial variation at all scales but also show their dependence on assimilation frequency and rainfall events. This analysis will help us understand the model response as a function of scale. It also helps in developing a better framework for specifying the error statistics in the assimilation algorithm. [Kumar, 1999] Kumar, P., A Multiple Scale State-Space Model for Characterizing Subgrid Scale Variability of Near-Surface Soil Moisture, IEEE Transactions on Geoscience and Remote Sensing, 37(1), January 1999.

H11B MCC: 3024 Monday 0800h

Optimization for Model Calibration and Management in Water Resources I *(joint with NG)*

Presiding: **C A Shoemaker,** Cornell University**; S Sorooshian,** University of California, Irvine

H11B-01 0800h

Assessing Model Structural Uncertainty Using a Split Sample Approach for a Distributed Water Quality Model

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A method for assessing model structural uncertainty as opposed to the more commonly investigated parameter uncertainty is presented that should aid in the development of improved water quality models. Elsewhere (see van Griensven and Meixner abstract, this session) we have developed a methodology (ParaSol) to estimate model parameter uncertainty. Uncertainty is typically estimated with a specific time period of data. However from experience with model calibration problems we know that we need to employ split sample and other evaluation tests to estimate the confidence we should have in our models and our methods. Evaluation tests generally give us qualitative data about confidence in our models. Here we propose a method that uses the split sample approach to generate a quantitative estimate of model structural uncertainty. The Sources of Uncertainty Global Assessment using Split SamplES (SUNGLASSES) method is designed to assess predictive uncertainty that is not captured by parameter or physical input uncertainty. We assume that this additional uncertainty represents model structural error in how the model represents the physical, chemical, and biological processes incorporated into water quality models. This method operates by selecting a threshold for a sample statistic (bias in our case), when the sample statistic for a model simulation is below the threshold the simulation is acceptable. Where this methodology differs from others is that the threshold is determined by evaluating whether the chosen threshold will capture simulations during an evaluation time period (hence split sample) that was not used to initially calibrate the model and generate parameter estimates. Most existing methods rely solely on sample statistics during a calibration period. The new method thus captures an element of predictive error that originates in the structural conception of the processes controlling water quality. The described method is applied on a Soil Water Assessment Tool (SWAT) model of Honey Creek, a tributary of the Sandusky catchment in Ohio. Water flow and sediment loads are analyzed. The results show the minor importance of model parameter uncertainty assessed by ParaSol in view of the total model uncertainty that was assessed by SUNGLASSES.

H11B-02 0815h

Parameter uncertainty assessment for distributed water quality models

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A new method is developed by the authors that assess the parameter uncertainty in distributed water quality models for multiple outputs in an efficient and effective way. Distributed water quality models have a high number of parameters, high parameter correlations, several output variables and a complex structure leading to multiple minima in the objective function. General uncertainty/optimization methods based on random sampling as GLUE or local methods such as PEST are often not applicable for theoretical or practical reasons. Therefore, the method "ParaSol" (Parameter Solutions) is developed to perform optimization and model parameter uncertainty analysis for complex models such as distributed (water quality) models. Optimization is achieved by adapting the SCE-UA to enable it to account for multi-objective problems while not being trapped in a localized minimum. The simulations performed by the SCE-UA are further used for uncertainty analysis. Two methods have been developed that select "good" parameter solutions out of the SCE-UA simulations based on an objective threshold. The first method is based on chi-squared statistics to delineate the confidence regions around the optimum/optima. The second method uses Bayesian statistics to define high probability regions whereby it accounts for the fact that the high probability regions are likely to be sampled more densely. The application of ParaSol on the flow and sediments simulations for Honey creek (Ohio) showed that, when 2 years of daily data are used, the confidence regions are very small when the chi -squared statistics are used and even smaller when using the Bayesian statistics. The results were also used to validate the suitability of SCE-UA sampling for uncertainty analysis by comparing to 500000 Monte Carlo samples. It was shown that the SCE-UA sampling was more effective and efficient as none of the Monte Carlo samples were close to the minimum or within the confidence region defined by ParaSol.

H11B-03 0830h

Combined Parameter and State Estimation of Hydrological Models Using Ensemble Kalman Filter

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