models to integrate soil, vegetation, hydrology and sediment transport to forecast and understand the functional interactions which occur over decadal and longer time spans

H41H MCC: 3024 Thursday 1020h

Use of Remotely Sensed Boundary Conditions in Land Surface Modeling II *(joint with A, B, GC)*

Presiding: **W P Kustas,** USDA Agricultural Research Service**; W Crow,** USDA Agricultural Research Service

H41H-01 1020h INVITED

Large Eddy Simulation over Heterogeneous Terrain with Remotely Sensed Land Surface Conditions

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A framework is developed to explore the coupling between the land and the atmospheric boundary layer using three dimensional turbulence simulation over remotely sensed land surface images. The coupled set of equations is integrated with boundary conditions from day 221 of the Monsoon90 experiment and analysis is conducted to quantify the transmission of surface heterogeneity information into the ABL. The LES model incorporates: radiant energy availability; spatial fields of remotely observed surface cover, temperature, and moisture; and, the ability to account for the separate contributions of soil and vegetation (i.e. two sources) to the mass and energy exchanges. Analysis of the results reveals: (i) that the combination of remotely sensed data and LES (in the absence of free parameters) yields regionally averaged land surface fluxes and ranges of spatial variability in the fluxes that compare well to similar measures from a network of flux measuring stations, (ii) that the correlation between time averaged surface and air temperatures is dependent on the length scale of the surface features, (iii) that the horizontal standard deviation of mean air temperature decreased logarithmically with height in the atmospheric surface layer; and (iv) that the mean air temperature contains spatial variability induced preferentially from variations in surface temperature occurring at scales greater than 500-1000 m. Hence, the feedback strength between the land and the atmosphere is shown to be scale-dependent for the range of length scales (i.e. $<$ 10km) studied here.

H41H-02 1035h

Effects of spatial aggregation on land-atmosphere interactions using large-eddy simulations LES) with a Lagrangian dynamic model

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A numerical study of land-atmosphere interactions in the atmospheric boundary layer (ABL) is performed using the large-eddy simulation (LES) technique. The LES uses the Lagrangian dynamic sub-grid scale model in which the eddy-viscosity coefficient is obtained from the large scales of the simulation rather than being imposed in an ad-hoc fashion by the user. Results of a simulation of the diurnal cycle of ABL evolution are used to illustrate the robustness of the Lagrangian dynamic model in adapting locally and temporally to the changes in atmospheric stability. Then, a remotely-sensed dataset of the skin temperature from USDA-ARS El Reno experiment is integrated as a bottom boundary condition in the LES. The Lagrangian dynamic model yields spatially varying coefficient fields that are well adapted to the innate heterogeneity brought about by the inclusion of remotely-sensed data. Spatial aggregation at various scales is subsequently used as a tool to investigate high-resolution LES and quantify the influence of embedded heterogeneity in the remotely-sensed boundary condition on the surface fluxes and land surface-atmosphere interactions.

H41H-03 1050h

Assessing the Spatial Scales of Surface-Atmosphere Interactions

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The coupled large-eddy simulation-remote sensing approach is used to investigate the influence of surface length scales on the atmospheric boundary layer. We focus on the interactions between remotely sensed surface conditions (NDVI and radiometric temperature) and large-eddy simulation derived scalar and flux properties in the lower atmosphere. Data available from the SMEX'02 field campaign is utilized to investigate two contrasting days. The first day, July 1, was representative of relatively high heterogeneity in which the remotely sensed data is characterized by high spatial variance in both the NDVI and temperature fields. The second day, July 8, was following rapid crop growth and a rain event which both acted to decrease the spatial variability. This allows investigation of both the influence that the length scales of surface variability has on the lower atmosphere, as well as the effect of the magnitude of contrast in the surface features. Wavelet co-spectra are used to investigate the influence that the spatial length scales calculated from the remotely sensed data has on the persistence of spatial variance into the lower atmosphere. Implications concerning the role of the atmosphere in 'filtering' the surface variability and the calculation of areal averaged fluxes over heterogeneous terrain will be discussed.

H41H-04 1105h

On the Operational use of Satellite Remote Sensing of Land Surface Properties in Numerical Weather Prediction

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Currently, approx. 1.000.000 satellite observations are assimilated into ECMWF's (European Centre for Medium-range Weather Forecasts) operational Integrated Forecast System within every 12 hour analysis cycle. None of these observations is used by the land surface module or refers to a land surface parameter. In this presentation, an overview of the pre-operational activities regarding the assimilation of satellite data in the land surface analysis is given. The first part of the presentation will address the snow analysis, which has recently been revised by using the satellite based NOAA NESDIS snow cover product. A comparison with independently derived MODIS snow cover shows a significant improvement of the analysis product. The impact of this revison on the weather forecast will be demonstrated. The second part of the presentation comprises the assimilation of soil moisture. A comparison between operational soil moisture products and remotely sensed data based on the Southern Great Plains 99 experiment demonstrates the potential of remotely sensed data. The impact of remotely sensed soil moisture is shown in assimilation experiments. When used in synergy with screen-level parameters, which are currently used in ECMWFs soil moisture analysis system, L-band microwave brightness temperatures are leading to an improved description of the land surface state, especially under conditions characterized by erroneous rainfall forcing data.

H41H-05 1120h

The simultaneous retrieval of surface evaporative fraction and heat transfer coefficients using variational data assimilation and surface radiometric temperature observations

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Recent advances in land data assimilation have yielded data assimilation techniques designed to solve the surface energy balance based on remote observations of surface radiometric temperature and a simple prognostic equation for surface temperature. These approaches have a number of potential advantages over existing diagnostic models, including the ability to make energy flux predictions between satellite overpass times, more physically realistic representations of ground heat flux, and reduced requirements for ancillary parameter estimation. Of particular interest is the variational approach presented by Caparrini et al. (Journal of Hydrometeorology, 2003) which uses a force-restore equation for surface temperature as a constraint for the simultaneous estimation of both evaporative fraction and bulk heat transfer coefficients from sequences of surface radiometric temperature observations. Using eddy correlation flux tower data and analogous energy balance results obtained from the diagnostic Two-Source Model (TSM), this presentation will examine the performance of the Caparrini et al. algorithm over a range of vegetative and hydrologic conditions in the southern United States. Results identify circumstances under which the simultaneous - and unambiguous - retrieval of both surface evaporation fraction and heat transfer coefficients is possible and clarify parameter interpretation issues associated with the single-source geometry of the variational approach. Inter-comparison with the TSM model illustrates circumstances under which the increased parameter complexity of the TSM model is justified by its more accurate two-source representation of thermal emission from partial vegetation canopies. Potential improvements to current variational data assimilation techniques will also be discussed.

H41H-06 1135h

Spatio-Temporal Disaggregation of Remote Sensing Observations for Land Surface State and Flux Estimation Using an Ensemble Data Assimilation Framework

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Precipitation is the key forcing variable for land surface hydrologic processes and is largely responsible for variability in soil moisture and surface flux fields. The measurement of precipitation over large scales is difficult due to its inherent spatial and temporal intermittency and the lack of sufficiently dense ground-based monitoring networks in many regions of the globe. Methods for remotely sensing precipitation are now generally available, but provide estimates that are spatially coarse (e.g. tens to hundreds of kilometers) and aggregated in time (daily to monthly). Due to the nonlinearity of surface hydrologic processes, these products cannot be directly used in modeling studies. Furthermore, for accurate hydrologic state and flux predictions it is crucial that uncertainty in these estimates must be properly incorporated into modeling frameworks. In this paper we present a unified ensemble data assimilation framework that contains a spatio-temporal disaggregation scheme for remotely sensed precipitation and incorporates remotely sensed microwave brightness measurements of the land surface in order to estimate distributed land surface states and fluxes. The ability to downscale coarse precipitation and radiobrightness observations is tested in experiments using data from the SGP97 field experiment. The spatio-temporal disaggregation scheme takes advantage of the ensemble nature of the Ensemble Kalman Filter (EnKF) by introducing precipitation realizations that are conditioned on the remote sensing data. This approach not only captures the large scale spatial variability in precipitation contained in the remote sensing observations, but introduces a more realistic error structure in the precipitation forcing that accounts for errors in storm magnitudes, arrivals, and spatial structure. Results from

tests using the remotely sensed precipitation show improvement in both soil moisture and land surface flux estimates over those using sparse ground-based precipitation.

H41H-07 1150h

Multiscale Kalman Filter for Optimal Assimilation of Near-Surface Soil Moisture into VIC-3L

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We undertake an alternative and novel approach to assimilation of near-surface soil moisture into land surface models by means of an extension of multiscale Kalman filtering (MKF). While most data assimilation studies rely on the assumption of spatially independent near-surface soil moisture observations to attain a computationally tractable problem, MKF allows us to explicitly and very efficiently model the spatial dependence and scaling properties of near-surface soil moisture fields. Additionally, the Expectation Maximization (EM) algorithm is used in conjunction with MKF so that the statistical parameters inherent to the assimilation algorithm may be optimally determined directly from the data at hand and allowed to vary over time. This constitutes a significant advantage since these parameters (e.g., observation and model error noise variances) largely determine the performance of the assimilation approach and have so far been most commonly prescribed heuristically and not allowed to evolve in time. We apply MKF to assimilate the near-surface soil moisture fields derived from ESTAR during the Southern Great Plains Hydrology experiment of 1997 (SGP97) into the Three-layer Variable Infiltration Capacity (VIC-3L) hydrologically based land surface model. We extensively test the relevance of using optimal statistical parameters for assimilation and thoroughly evaluate the effect that the spatial resolution of the ESTAR data has on improving the predictive capabilities of VIC-3L. The results obtained show that assimilation greatly improves the spatial structure of near-surface soil moisture as predicted by VIC-3L. Moreover, VIC-3L seems capable of conveying the assimilated information forward in time. Significant impacts on the way VIC-3L partitions energy fluxes are also observed to result from assimilation of near-surface soil moisture.

H41H-08 1205h

Surface Soil Moisture Assimilation From ASAR Imagery for Root Zone Moisture Predictions at Basin Scale

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The state of the root-zone soil moisture is a key variable controlling surface water and energy balances. Emerging efforts in data assimilation seek to guide land surface models (LSMs) with periodic observations of surface soil moisture. Montaldo et al. (Water Resour. Res., 2001) and Montaldo and Albertson (Adv. Water Resour., 2003) developed an operational multi-scale assimilation system for robust root zone soil moisture predictions at the local scale. The assimilation scheme, developed for a force-restore method based LSM, updates the measured surface soil moisture, the root zone soil water content and the soil hydraulic conductivity, in a manner that compensates for both inaccurate initial conditions and model parameter estimates. In this presentation we describe the development and testing of an operational assimilation system for robust root-zone soil moisture predictions at the basin scale. High resolution data of the new ASAR (advanced synthetic aperture radar) sensor aboard European Space Agency's Envisat satellite offers the opportunity for monitoring surface soil moisture at high resolution (up to 30 m), which is suitable for distributed mapping within the small scales of typical Mediterranean basins. Indeed, adequate spatio-temporal monitoring of the soil moisture is essential to improve our capability to simulate the water balance. As part of a recently-approved European Space Agency (ESA) Envisat AO project, ASAR-based soil moisture mapping of the Mulargia basin (area of about 65 sq.km), sub-basin of the Flumendosa basin in Sardinia, are available . This semi-arid basin has a key role in the water resources management of Sardinia. Semi-arid regions, such as Sardinia island, suffers from water scarcity, which is increasingly due to the broad desertification processes of the Mediterranean area. Within the basin, land surface fluxes are well monitored through two evapotraspiration measurement systems (one eddy correlation technique based station, and one Bowen ratio station), and spatially distributed soil moisture ground-truth data needed to assess the ASAR imagery are collected over the whole basin through the TDR technique and the gravimetric method. The objectives of this work are to: 1) test the high resolution ASAR imagery accuracy for producing maps of surface soil moisture patterns at the catchment scale, 2) develop and test an operational assimilation system for robust root-zone soil moisture predictions at the basin scale. The developed assimilation system will have two components, 1) ASAR observations will be merged with the model for robust surface soil moisture estimates though the Ensemble Kalman Filter, and 2) the surface soil moisture estimates will then drive an assimilation engine for robust root-zone soil moisture predictions.

H42A MCC: Level 2 Thursday 1330h

Observations and Theoretical and Numerical Studies of Land Surface Heterogeneities on Land-Atmosphere Modeling Posters *(joint with A)*

Presiding: **J Chen,** University of California, San Diego**; E Maurer,** Santa Clara University

H42A-1057 1330h POSTER

Soil Water Access Heterogeneity in Land-surface Parameterisation Schemes

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Confidence in Atmospheric General Circulation Models' (AGCMs') predictions, the predominant tools with which we predict future climate, depends on successful validation of their simulations. Land-surface climates, particularly important for people as the land is where we live and grow food, suffer from the lack of high quality global observational datasets of variables such as evapotranspiration and soil moisture that are not directly observable at scales appropriate to atmospheric models. We evaluate simulations by 20 AGCMs participating in the second phase of the Atmospheric Model Intercomparison Project (AMIP2) (Phillips *et al.*, 2002, Irannejad *et al.*, 2003) under the auspices of the Project for Intercomparison of Land-surface Parameterisation Schemes (PILPS, Henderson-Sellers *et al.*, 2002), against available observations and reanalyses along with a global off-line land surface simulation by the Variable Infiltration Capacity (VIC) scheme. Our hypothesis is that the largest contribution of soil moisture variability to precipitation variability will arise in models that use land-surface parameterization schemes (LSSs) that derive the largest fraction of their evapotranspiration from rooting zone soil moisture. This is based on the Dickinson *et al.* (2003) suggestion regarding differences in the partitioning of evapotranspiration and the Henderson-Sellers *et al.* (2003) demonstration that different LSSs cause differences in the prediction of continental surface climates that are not compensated by atmospheric feedbacks in coupled simulations. Underlining the importance of land-surface parameterization for climate prediction, Koster *et al.* (2002) demonstrated that different LSSs coupled to different GCMs generate a wide range of simulations of precipitation and its variability resulting from soil moisture variability. Here we use the AMIP2 results to (i) examine the validity of the Dickinson *et al.* hypothesis; and (ii) discover a means of ranking LSS parameterizations.

H42A-1058 1330h POSTER

Investigating Effects of Land Surface Cover Heterogeneity on the Uncoupled and Coupled RSM and VIC

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The Variable Infiltration Capacity (VIC) macroscale hydrologic land surface model is being coupled with the Regional Spectral Model (RSM). The land surface heterogeneity in VIC is modeled by representing one sub-grid for one vegetation type in each model grid. Increasing the number of sub-grids in each grid will improve modeling land cover heterogeneity at the expense of an increased computational burden. Our goal is to explore the significance of land cover heterogeneity by investigating the influence of increasing heterogeneity on the simulated soil moisture, surface runoff and baseflow, and fluxes between the land and the atmosphere. In particular, we are developing off-line and coupled experiments. For the off-line experiments we are using one-day forecast products from the coupled VIC and RSM model along with observed precipitation from the Climate Prediction Center (CPC) as forcings. These off-line experiments will then be compared to coupled experiments initialized from the offline runs. We focus in particular on the semi-arid areas over the southwestern United States, i.e., the study region of the project for the Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA).

URL: http://ecpc.ucsd.edu/projects/uastc/

H42A-1059 1330h POSTER

A Simple Model to Determine the Effects of Surface Inhomogeneity in the Inner Region

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Remote sensing has potential to provide measurements of water vapor content over larger areas with fairly high spatial and temporal resolution. Over a horizontally homogeneous area, these measurements can be used to calculate evaporation for the entire region measured. However, there are problems in areas of heterogeneity: because of wind and turbulent mixing in the atmosphere, water vapor concentration gradients at one location may not be a good estimate of evaporation at that exact surface location. A model has been developed to predict the effects of single and multiple surface emission step changes on water vapor concentrations profiles. Using this model, correction factors are suggested for the determination of evaporative fluxes using the Monin-Obukhov similarity method. These correction factors adjust the concentration profiles for an upwind step change in emission rates given a neutral atmosphere. The addition of a correction factor for various atmospheric stabilities will be presented which will move further towards estimating evaporation over a heterogeneous surface.

H42A-1060 1330h POSTER

Calibration Strategies for Global Land Surface Modeling

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Simulated datasets of global land surface fluxes and states are a major element of strategies to evaluate the effect of global warming on the land surface hydrologic

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