H62C-0885 1330h POSTER

Scales of Topographic Dependence of Alpine Precipitation

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Scales of topographic dependence of daily precipitation over the Swiss Alps are examined using a new multivariate precipitation interpolation technique. The method of additive regression splines has been designed to incorporate spatially varying dependences on several topographic variables. It avoids the "curse of dimension" by restricting the underlying spline structure to be two-dimensional. This is in keeping with the overall goal of delivering essentially two-dimensional maps. Moreover, it permits a separation between physical process, as represented by various topographic variables, and the empirically determined, continuous two-dimensional effects of these variables on precipitation across the landscape.

The analysis determines horizontal and vertical scales of the interaction of precipitation with topography. A common limitation with existing precipitation interpolation methods lies in their difficulty in identifying effective topographic parameters other than elevation. Orographic effects associated with slope and aspect are often discussed but are not always statistically significant. The effects of two topographic parameters, the northern and eastern components of the unit normal to an appropriately vertically exaggerated digital elevation model, are investigated. These parameters have some basis in process modelling studies and, unlike topographic aspect, are continuous functions of horizontal position. They are used to identify significant topographic aspect effects on precipitation without prior knowledge of the prevailing wind field.

Short range correlation structure has rarely been explicitly identified in precipitation interpolation studies but its impact is surprisingly strong. Evidence for its existence in these precipitation data was provided in an earlier study but effective methods for calibrating such correlation in spline analyses have only recently been developed. The spatial scale of correlation found here, around 5 km, is large enough to permit its calibration from the data network. This entails a significant reduction in complexity of the fitted additive regression splines and in fact directly facilitates their calibration. This short range correlation structure appears to be closely linked to the horizontal scale of topographic dependence. Moreover, it suggests that there are intrinsic limits to the accuracy of precipitation fields interpolated from standard precipitation gauge networks. This has significant implications for spatial precipitation analyses and the design of effective precipitation gauge networks.

URL: http://cres.anu.edu.au/

H62D MCC: Hall C Saturday 1330h

Progress in Hydrometeorological Data Assimilation Posters *(joint with A, B, GC)*

Presiding: **P Houser,** NASA Goddard Space Flight Center**; R Reichle,** NASA Goddard Space Flight Center

H62D-0886 1330h INVITED POSTER

Overview of the European Land Data Assimilation System (ELDAS) Project

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The European Land Data Assimilation System (ELDAS) project aims at the construction and evaluation of a routine system for soil moisture initialization in NWP applications. It is partially inspired on the US Global Land Data Assimilation System (GLDAS) Project, but for the time being is limited to soil moisture estimation. Also it is not intended to operate on a near-realtime basis during the duration of the project.

The paper will present a brief overview of the structure and goals of the ELDAS project. Also, a number of examples will be shown of forcing data bases of precipitation, surface radiation and surface temperature changes that have been produced so far.

The European Union has funded the ELDAS project, which will run until late 2004.

URL: http://www.knmi.nl/samenw/eldas

H62D-0887 1330h POSTER

A soil Moisture Analysis System for ELDAS

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Within the framework of the European Land Data Assimilation system (ELDAS) a soil moisture analysis scheme is built for the optimal estimate of soil moisture. The aim is to combine different sources of information on soil moisture: 2m temperature, relative humidity,IR heating rate and microwave brightness temperature observations. The system is developed and tested with a single column model (SCM) version of the full ECMWF-numerical weather prediction model. The SCM is forced with ERA40 data, but precipitation and solar radiation are prescribed from observations to avoid errors in the forcing crucial for soil moisture. The soil moisture analysis is based on a 1DVAR system with a Kalman filter (KF) update of the background error covariance matrix. Additionally, an approach to adapt the model error covariance matrix at each cycle is tested (adaptive KF).

In a first step only 2m temperature and relative humidity observations are assimilated. The model results for two different case studies (FIFE 1987 and MUREX (France) field experiments) show that the new assimilation system performs better than systems based on optimal interpolation (currently operational at ECMWF) or nudging (operational till 1999 at ECMWF). The main reason for the improved performance of the 1DVAR scheme is that in this framework the gain matrix depends on the synoptical situation rather than being fixed to statistically derived values. Current work includes the incorporation of IR heating rates and brightness temperatures into the system and testing with the MUREX and SGP97 data sets.

H62D-0888 1330h POSTER

Assimilation of Latent Heat Fluxes and Soil Moisture Values Into a Land-Surface Model Through a Kalman Filtering-Based Method

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We investigate the possibility to improve the performance of hydrological models through the assimilation of both observed soil moisture values and latent heat fluxes. The study is performed on a small hillslope in the Zwalm catchment in Belgium, which is equipped with Bowen-ratio energy balance and eddy-correlation instruments. A methodology to assimilate both the soil moisture values and latent heat fluxes based on extended Kalman filtering is developed. An extended Kalman filter is used to assimilate the soil moisture values. Analogue equations are derived to assimilate the latent heat fluxes, resulting in an assimilation algorithm similar to the extended Kalman filter. The assimilation methodology is then applied to the in-situ measurements. The effect of the assimilation of either the soil moisture values or the latent heat fluxes, or a combined assimilation, is assessed. It is found that the assimilation of the soil moisture measurements has a small impact on the modeled energy balance terms, and that the assimilation of the measured latent heat fluxes has a small impact on the modeled soil moisture values. This can be explained by the good performance of the model before the assimilation procedure. The best model results are obtained when the soil moisture and latent heat flux observations are simultaneously assimilated into the model.

H62D-0889 1330h INVITED POSTER

Assimilation of Remotely-Sensed and Micrometeorological Station Observations into a Coupled Land Surface-Atmospheric Boundary Layer Model

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The most effective way to obtain land surface fluxes of moisture and energy with the accuracy and coverage required for hydrologic and meteorological applications is to merge information from satellites, ground-based stations, and models. In our recent work we have designed a framework for the estimation of land surface states and fluxes through the assimilation of remotely sensed and micrometeorological station observations into a coupled land surface-boundary layer model. Satellite-based surface radiance measurements are typically characterized by infrequent sampling, and are sensitive only to the state in the upper few centimeters of the soil column. Because of the strong coupling between the land surface and overlying atmospheric boundary layer, valuable information about subsurface states and surface fluxes is contained in available surface layer and boundary layer observations (micrometeorological temperature and humidity, radiosonde data, satellite-based soundings, etc.). Using the coupled model requires minimal auxiliary information and variables that are typically required as forcing for offline models (and often available at higher temporal resolution) can instead be assimilated with satellite-based radiance measurements, providing a further constraint on the flux estimates. In this work we present results using both variational and ensemble filtering approaches applied to the First ISLSCP (International Satellite Land Surface Climatology Project) Field Experiment (FIFE) site in Kansas.

H62D-0890 1330h POSTER

Assimilation of Multi-resolution Passive and Active Remote Sensing Data for the Estimation of Soil Moisture Fields

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The objective of this study is to estimate surface soil moisture fields using low frequency microwave (L-band) radiobrightness and backscatter measurements. The relative advantages of each of these measurement sources (resolution for radar and greater sensitivity for radiometer) are combined in the data assimilation framework (ensemble Kalman filter). In this framework, a dynamic model of land surface processes is used to generate an ensemble of prior estimates by randomizing the uncertain parameters and forcing variables. When measurements are available, a multi-resolution measurement operator is used to estimate prior radiobrightness and backscatter values that can be merged with remotely sensed observations at their native resolutions. Posterior estimates of soil moisture fields conditioned on the observations are thus produced. In this study a framework for evaluating the advantage of assimilating active along with passive measurements is introduced. The representation of smaller scale variability where radar data are included may affect algorithmic issues such as the minimum number of ensemble members required for robust estimation. Criteria for the implementation of the data assimilation system for this estimation problem are also introduced.

H62D-0891 1330h POSTER

Estimation of Surface Energy Balance Components Over the US Midwest using Multi-Platform and Multi-Resolution Satellite Measurements

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A multi-resolution data assimilation system is introduced that estimates the main determinant parameters of land surface energy balance (turbulent transfer coefficient for heat fluxes CB and evaporative fraction EF). These parameters are used to compute land surface latent and sensible heat fluxes. Satellite data from multiple platforms (GOES geostationary Vis/IR, NOAA-series AVHRR Vis/IR and DMSP-series SSM/I microwave) are used to estimate fields of land surface evaporation over the US Midwest for a four-month warm-season period in 1997. Besides the satellite data on temperature and incident radiation at the surface, the assimilation system requires air temperature and wind-speed that here are derived from micrometeorological stations. No other forcing data or empirical parameters derived from land classification, etc. is needed for the thermal model that is included as a constraint in the adjoint-state variational approach to assimilation. Diurnal cycle of retrieved energy balance components and the day-to-day variations in land evaporation are tested against ground-based flux-station measurements. The retrieved field patterns of estimated parameters and surface flux components are related to landscape features over the US Midwest in another test of the approach. The application presented here demonstrates the capability at hand to estimate global and dynamic fields of land evaporation from existing multi-resolution sensors in a computationally efficient and parsimonious fashion.

H62D-0892 1330h INVITED POSTER

Prospects for improving land surface model performance via the assimilation of remote sensing products.

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An ongoing challenge for hydrologists and remote sensing scientist is the design of experiments to demonstrate the value - in any - of remote sensing observations for efforts to monitor and/or predict surface hydrologic processes at large scales. The need is especially pressing for remote observations of surface geophysical state variables like soil moisture and skin temperature. The most efficient utilization of remote surface state observations is within the context of a data assimilation system designed to merge surface state predictions from numerical models with remote observations of the land surface. Such systems contain at least three components: a numerical land surface model, an emission model to convert land surface model predictions into observable quantities (e.g. brightness temperature), and an assimilation algorithm. The 'value' of remote sensing observations therefore depends on a myriad of factors including the quality of non-updated open-loop model predictions, the optimality of the data assimilation approach, and the accuracy of the observational model. One basic benchmark for data assimilation approaches should be the accuracy of model predictions (e.g. evapotranspiration) obtainable from non-updated open-loop model simulations. This talk will address some of the basic issues surrounding such evaluations and examine ways in which remote sensing observations can add skill or value to land surface model predictions.

Two key weaknesses of land surface models are their reliance on uncertain measurements of meteorologic forcings (e.g. rainfall) and parameter selection ambiguities presented by their complex representation of surface processes. Both shortcomings represent potential openings for land data assimilation approaches. The first part of the talk will examine the potential of remote L-band microwave brightness temperatures data and an Ensemble Kalman filter to compensate land surface model predictions for errors arising from poor or nonexistent rainfall measurements. Strategies for merging remotely sensed surface soil moisture retrievals with sparsely sampled rainfall rates from a spaceborne radar precipitation mission will also be discussed. The second portion of the talk will evaluate the accuracy of proposed variational assimilation approaches designed to combine remote skin temperature retrievals with a simplified prognostic equation for surface soil temperature. Such approaches offer an attractive alternative to more complex representations of the surface energy balance since the increased accuracy of the more complex approaches must be discounted by the practical difficulties presented by their calibration over heterogeneous landscapes.

H62D-0893 1330h POSTER

Uncertainty Assessment for River Discharge Estimates Based on Satellite Radar Altimetry Sampling

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Satellite radar altimetry, which is used extensively for measuring ocean water surfaces, may also produce accurate information on inland water levels. As a result, satellite radar altimetry sampling of river water levels has been suggested as a means for discharge estimation for major rivers worldwide. In this study, numerical experiments are used to assess uncertainties in discharge estimates based on satellite water levels. Specifically, historical records and flow rating curves for U.S. Geological Survey gages in the Upper Mississippi River basin are used to simulate satellite water level observations for hypothetical satellite design characteristics. These synthetic satellite water levels are then used to estimate river discharges. Two estimation approaches are examined. In the first, discharge is estimated independently at each site at the time of the satellite overpass. In the second, variational data assimilation is used with a simple hydrologic routing model to estimate discharge at all the sites over a fixed time window. This second approach has the ability to exploit dynamic information on the passage of flood waves through the river network provided by satellite observations at multiple sites. In the numerical experiments, the simulated sequences of satellite-generated flows are compared to the observed flows to quantify errors expected from satellite sensors. Synthetic satellite observations are generated for different satellite orbital repeat periods and for different levels of sensor uncertainty to examine how these parameters affect discharge estimates over daily to annual time scales.

H62D-0894 1330h POSTER

Soil Moisture Intialization for Climate Predictions: Assimilating SMMR into a Land Surface Model

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Current climate models either for seasonal prediction or for water resource management are limited due to poor initialization of land surface soil moisture states. Passive microwave remote sensing provides quantitave information of water content at a very thin near-surface soil layer at large scale. These information can be assimilated into a land surface model to retrieve better soil moisture states. A Kalman filter-based data assimilation strategy is currently installed in a catchement-based land surface model(CLSM) in NASA Seasonal-to-Interannual Prediction Project(NSIPP). We use this algorithm to assimilate Scanning Multifrequency Microwave Radiometer (SMMR) data for the perid of 1979-1987 and compare the asimilated soil moisture with in-situ measurements collected in Russia, Mongolia and China. Our comparison results show the data assimilation method used here significantly improve soil moisture estimation. Our study demonstrates 1).The Kalman filter-based assimilation is a feasible approach which can be used to link remote sensing and land surface models for improved climate prediction; 2). SMMR data can provide better intialization of soil moisture states for the period of 1979-1987 for retrospective study in NSIPP; 3) Our algorithm can also be used to assimilate data collected from the Advanced Microwave Scanning Radiometer for the Earth (AMSR-E) observing system instrument on the current EOS Aqua satellite to provide better soil moisture states for real time forecasting.

H62D-0895 1330h POSTER

Estimation of Model Error Covariance Matrices of Extended Kalman Filter for Validation of AMSR-E Soil Moisture Product

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Due to imperfect instrument calibration and inversion algorithms, geophysical noise, representativeness error, communication breakdowns, and other sources, land surface soil moisture retrieved from satellite or aircraft remote sensing instruments contain uncertainties. As an effort of NASA's AMSR-E Science and Validation Team, the extended Kalman filter (EKF) data assimilation scheme is implemented in NASA's Land Data Assimilation System (LDAS) for the validation of the surface soil moisture product. A key step of this validation approach is the determination of the covariance matrices of model errors. In this study, a series of numerical experiments on the sensitivity of EKF output to different hypothetic model error covariance settings is carried out using the Mosaic model in the LDAS and the surface soil moisture data derived from the brightness temperature observations by the Tropical Rainfall Measurement Mission (TRMM) Microwave Imager (TMI) for the area of Southern Great Plains Hydrology Experiment 1999 in Okalahoma. By introducing various types of errors into the derived soil moisture data, the best model error covariance settings for correcting the introduced hypothetic observations errors are investigated. In addition to these stationary settings for model error statistics, parameterization schemes of nonstationary characteristics of model error covariance are also tested. Results of the numerical experiments and performance of EKF using the nonstationary model error covariance parameterizations for correcting the various types of observation error will be presented.

URL: http://land.gsfc.nasa.gov/~~xzhan/Zhan_AGUfm02/

H62D-0896 1330h POSTER

A Parallel Ensemble Kalman Filter for Four-dimensional Land Data Assimilation

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Successful weather and climate forecasts may depend on the accurate initialization of the land surface states. To obtain land initial conditions, land model integrations and observations of land surface states can be merged using advanced data assimilation algorithms such as the Kalman filter. We present an ensemble-based four-dimensional assimilation algorithm that can ingest land surface observations into the Catchment Model of the NASA Seasonal-to-Interannual Prediction Project (NSIPP). The assimilation algorithm is fully parallelized. Ensemble integration between update times is inherently parallel. Sub-regions of the domain are updated in parallel using covariance localization (or compact support) techniques. A short overview of the algorithm is given. We also present preliminary results of retrospective soil moisture estimates that have been derived by assimilating soil moisture retrievals from the space-borne Scanning Multichannel Microwave Radiometer (SMMR) into the NSIPP Catchment Model.