H31A CC: 220 C-E Wednesday 0830h

Remote Sensing of Precipitation Posters *(joint with A, OS, GC)*

Presiding: **T L Bell,** NASA Goddard Space Flight Center**; M Steiner,** Princeton University

H31A-01 0830h POSTER

Using Space-time Multifractal Models of Rain for Simulating Satellite Rain Algorithms, Predictability, Nowcasting

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Rainfall nowcasting is currently performed with the help of sequences of radar or satellite derived rainfall surrogate fields, the usual assumption being that the field is "frozen" and is simply advected i.e. without any development. In this talk, we argue that space-time multifractal processes provide appropriate frameworks for modeling rain and that this can be used to forecast both the advection and the development. Necessary ingredients include the correct degree of space-time stratification, vertical-horizontal stratification as well as estimates of the basic (universal mulitfractal) parameters. In addition, special care must be given to numerical stability, and to structures larger than the model domain, and to small subpixel scale structures. We show theoretically and numerically that states with a shared past diverge algebraically (rather than exponentially) in time, and study the dependence on spatial scale. We also show how forecasts can be made using conditional expectations and quantify the error growth. We also show how such models can be used to replace current subsensor homogeneity assumptions by more realistic heterogeneity assumptions. In particular using stratified three dimensional multifractal models of liquid water distribution, we simulate radar reflectivity fields, effective reflectivity fields, infra red, visible radiances. Using these fields - which can be simulated at virtually any required resolution - we simulate satellite rain algorithms (RAINSAT) which estimates the probability of rain. We argue that such models are necessary for validating areal rainfall estimates.

H31A-02 0830h POSTER

Rainfall Downscaling by a Phase-Conserving, Nonlinearly-Transformed Autoregressive Model: Validation on Radar Precipitation Estimates

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The prediction of the small-scale spatio-temporal pattern of intense rainfall events is crucial for flood risk assessment in small catchments and urban areas. In the absence of a full deterministic modelling of small-scale rainfall, it is common practice to resort to the use of stochastic downscaling models to generate ensemble rainfall predictions to be used as inputs to rainfall-runoff models. Here we discuss a spatio-temporal downscaling procedure that we call the "Rain FARM: Rainfall Filtered AutoRegressive Model," based on a non-linear transformation of a linearly correlated (gaussian) field, and we validate this approach on a set of radar precipitation estimates. The Rain FARM procedure allows for reproducing the scaling properties (if any) of the rainfall pattern and it can be easily linked with meteorological forecasts produced by limited area meteorological models. We believe that this approach represents a significant improvement over commonly available models used for rainfall downscaling.

H31A-03 0830h POSTER

Comparison of the Scaling Characteristics of Rainfall Derived from Space-based and Ground-based Radar Observations

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The authors compare the scaling characteristics of tropical rainfall derived from the Tropical Rainfall Measuring Mission (TRMM) precipitation radar (PR) and the S-band ground-based radar (GR). Compared with the PR, the GR has a lower minimum detectable signal (-108 dBm instead of 17 dBZ); a better horizontal resolution (the gate spacing is 250 m, instead of 4.3 km resolution at nadir); and a nonattenuating wavelength (10 cm instead of 2.2 cm). The differences between the PR and GR radar characteristics and viewing geometries lead to important differences in sensitivity, attenuation, and resolution. Comparison of the scaling characteristics of rainfall derived from the GR and PR is helpful to identify the potential and limitation of the PR. In this work, the authors use the PR and GR data collected from three primary TRMM Ground Validation (GV) sites. This dataset includes 18 months of data from the Houston, Texas, site; 30 months from the Melbourne, Florida, GV site; and 11 months from the Kwajalein Atoll, Republic of Marshall Islands, GV site. The GR data used in this study are the current 2A-53 products prepared by the NASA TRMM Office. Under the assumption of scaling invariance, the authors perform a detailed comparison of the scaling properties of rainfall derived from the PR and GR rainfall products for the three sites. Results using the scaling of moments function show that (1) both products reveal that the scaling parameter, which characterizes the scaling of rainy regions, can be related to the large-scale spatial average rain rate by a one-to-one function, and the function parameters obtained from the PR and GR are remarkably similar; (2) the values of the scaling parameter, which characterizes the curvature of the scaling function, obtained from the PR are consistently lower than those obtained from the GR; and (3) the differences between the PR- and GR-derived scaling characteristics are attributed to the differences in the sensor characteristics, as the temporal sampling of the TRMM PR is shown to adequately capture the scaling properties of rainfall. The authors also investigate the assumption of scaling invariance using a simulation-based approach. Results show that more than 25% of the rain events do not exhibit scaling invariance in moment orders of 0 and 2. The behavior of the deviation from the scaling and its implication on the type of modeling cascade are discussed.

H31A-04 0830h POSTER

Scale-Dependence of Radar Rainfall Rates

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Scale differences may introduce a bias when comparing, merging, or assimilating rainfall measurements because the dynamic range of values representing the underlying physical process strongly depends on the resolution of the data. The present study addresses this issue from the perspective of how well coarser-resolution radar rainfall observations may be used for evaluation of hydrologic point processes occurring at the land surface, such as rainfall erosion, infiltration, ponding, and runoff. Conceptual and quantitative analyses reveal that scale differences may yield significant biases. Even for perfect measurements, the overall bias is composed of two contributing factors: one related to a reduction of dynamic range of rain rates and the other related to a dependence of the relationship between observed radar reflectivity factor and retrieved rainfall rate on the scale of observation. The effects of scale differences are evaluated empirically by averaging raindrop spectra observations in time. Averaging drop spectra over 5 min, on average over a large data set, resulted in an underestimation of median and maximum rainfall rates of approximately 50% compared to the corresponding 1-min values. Overall, standard deviations of rain rates retrieved from 5-min averaged radar reflectivity factors may easily be off a corresponding high-resolution (1-min) rainfall rate by a factor 2 or more. Scale difference effects are thus important and have to be considered when comparing, merging, or assimilating data from very different spatial and temporal scales.

H31A-05 0830h POSTER

Error Characterization of the Disdrometer Calculated Integral Rainfall Parameters

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As part of the NASA Tropical Rainfall Measuring Mission (TRMM) Ground Validation program, a network of six Joss-Waldvogel (JW) disdrometers have been operating collocated at NASA Wallops Flight Facility since October 2003. The disdrometers were installed in a rectangular grid where the spacing was 127 cm by 140 cm. Here, we will present the error characteristics of the disdrometer calculated rainfall and reflectivity measurements utilizing six JW disdrometer measurements for the period of October through December 2003. The JW disdrometer has been considered a standard instrument in measuring drop size distribution and widely used to derive the relationships between the radar measurements and rain rate. The study will intend to demonstrate at what accuracy the disdrometer can measure the rain parameters. The disdrometers are one of five surface instruments of the ground validation sites for the upcoming NASA Global Precipitation Measurement (GPM) mission and the measurement accuracies are considered as required element of the satellite validation products.

H31A-06 0830h POSTER

Error Characteristics of Disdrometers and Profilers Determined From Serial Reflectivity Measurements From Instrument Pairs

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Serial reflectivity measurements from paired instruments are examined during two field campaigns in order to determine the measurement errors of the instruments. The instruments studied are two collocated Joss-Waldvogel disdrometers (JWD) at Wallops Island, VA and two collocated profilers deployed at Ji-Parana, Brazil during TRMM LBA. Differencing the measured reflectivity from the instrument pairs eliminates most of the temporal variability of reflectivity making it possible to isolate instrument precision. The measured reflectivity differences from the paired disdrometers have a Gaussian-like distribution and an rms difference of 2.1 dBZ for individual minute samples . The time series of differences are not autocorrelated so that the standard error of the mean refectivity is found to be less than 0.1 dBZ for a 12-hour rain event. The measured reflectivity differences from the paired profilers also have a Gaussian-like distribution and an rms difference of 0.4 dBZ. The standard error was found to be 0.05 dBZ for a 90-minute stratiform rain event. Implications for the calibration of profilers using disdrometers and scanning radar using profilers are considered. The measurement precision estimates obtained here are substantially less than the 1 to 3 dBZ values commonly associated with the absolute calibration of operational scanning weather radars. A reference reflectivity of precision of a few tenths of a dBZ has the potential for substantially improving the calibration of scanning radars.

H31A-07 0830h POSTER

Evaluation of Radar Rainfall Estimation in Widespread Early Spring Rainfall Events

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Significant discrepancies can exist between actual and estimated rainfall with the interaction of biases and random error being documented in a number of studies. Numerous reports have demonstrated strong scale dependence in the uncertainties or errors in radar rainfall estimation strategies. This study addresses issues of scale, radar-range and uncertainty of weather radar rainfall measurements under early spring conditions. Rainfall measurement analysis is focused on XPOL (mobile X-band dual polarization weather radar) retrievals from late March through early May 2002 in Northeastern Connecticut, US. The applicable XPOL dataset has been refined through attenuation correction, considerations of contamination and vertical profiles adjustment and noise to twelve rainfall events at a base resolution of 300-meter grids every five minutes. XPOL measurements are validated with sixteen raingauges dispersed in the representative 424 km2 Mansfield Watershed at a maximum range of 23 km. The comparison dataset is taken from the NEXRAD stage-III bias adjusted hourly rainfall rates. This specific data is drawn from the most proximal National Weather Service radars in Upton, NY and Boston, MA each over 100 km away, demonstrating gridded rainfall on a 4-kilometer scale. Several statistical evaluations are employed to study the scale effects and cross-platform radar differences. XPOL radar observations are aggregated to coarser spatial grids; in successive aggregations we test the relative error of selected points against raingauge validation. Spatial XPOL data can be matched directly to NEXRAD stage III data thereby giving an indication of the internal variance of NEXRAD pixels. The assimilated internal variability of NEXRAD rain retrievals may offer insight into the bias and uncertainty of the system and information on the radar-gauge comparison uncertainty.

H31A-08 0830h POSTER

High-Resolution Rainfall Rate and DSD Estimation From X-Band Polarimetric Radar Measurements

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This study describes newly developed attenuation correction and microphysical retrieval methods for X-band polarimetric radar (XPOL). It concentrates on exploring the dependence of the retrieval on raindrop size distribution variability, and its sensitivity with respect to the selection of oblateness-size relation (or axial ratio) and maximum diameter limit. Variations in the assumed form of the raindrop axial ratio may result in significant biases in attenuation and microphysical retrievals. In addition, at this wavelength, resonance occurs for sizes larger than about 4 mm, and therefore several polarimetric variables exhibit non-monotone dependence on the drop diameter. An algorithm is developed and experimentally validated for retrieving DSD model parameters. The DSD model is assumed to be a three-parameter "normalized" gamma distribution. Simultaneous and closely matched radar rays from non-attenuated (S-band) dual-polarization radar measurements and corresponding DSD retrievals are used to validate the proposed XPOL algorithm in terms of attenuation correction, as well as DSD parameter retrievals.

H31A-09 0830h POSTER

Raindrop Size Distributions: Characterization and Retrieval from Polarimetric Radar Measurements

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Information regarding the raindrop size distribution (DSD) is important for accurate rain estimation with radar, for cloud microphysics studies, and for improving parameterization in numerical weather forecast models. In the paper, time series of ground-based video disdrometer observations of raindrop number concentration and mass distribution as well as values normalized by mass-weighted size and liquid water content for thunderstorms are presented. The observations reveal that the shape of rain DSDs depends on the stage of rain development and that there is no universal shape for rain DSDs even after normalization. An algorithm, based on disdrometer measurements and scattering calculations, for retrieving DSDs from polarimetric radar measurements is then described. Dubbed the constrained-gamma DSD retrieval method, the procedure uses radar reflectivity (Z), differential reflectivity (Z_{DR}), and an empirically determined relation between the shape (μ) and slope (Λ) parameters of the gamma DSD model. The constrained-gamma DSD model is similar to a normalized-gamma DSD in that both approaches use two independent parameters to characterize rain DSDs. But the constrained-gamma model allows different shape of DSD even after normalization. While the normalized-gamma model and other (fixed μ) retrieval algorithms can provide reasonable rain rate estimation from two remote measurements, the constrained-gamma DSD retrieval leads a much better agreement with in-situ measurements for number concentration and characteristic size as well as better microphysical parameters for forecast models. The constrained-gamma retrieval model is applied to a thunderstorm complex to study the spatial and temporal characteristics of the DSD.

H31A-10 0830h POSTER

The Effect of the Degree of Common Orientation of the Hydrometeors on Polarimetric Radar Observables

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We examine a polarimetric weather radar transmitting simultaneously horizontal (H) and vertical (V) polarized radiation without pulse train switching between orthogonal states. For simultaneous reception of both complex signal amplitudes at H and V polarization the radar observables representing the radar signal from an ensemble of particles filling a radar resolution volume are reflectivity, Z_H, differential reflectivity, Z_{DR}, copolar correlation coefficient at zero lag time, ρ_{HV}, and total differential propagation phase shift,$\Phi = \phi_{DP} + \delta$, where ϕ_{DP} is the differential propagation phase shift, and δ is the backscattering differential phase shift. Of primary interest for precipitation measurements is the calculation of the specific differential phase K_{DP} (which is the slope of ϕ_{DP} with range), since it is a better estimator of precipitation at high rain rates than reflectivity alone. Because ϕ_{DP} is range cumulative the negative values of K_{DP}, which are frequently observed, are attributed to the backscattering phase. However, recently it has been shown theoretically that part of the range variation of Φ could be due to the variation of the degree of common orientation of the hydrometeors when the radar beam moves from a region of well oriented particles to a region of less oriented ones. Data already published in the literature and from the McGill polarimetric operational S-band radar are presented. Range profiles crossing the melting layer, and a hail shaft are examined. It will be shown that the negative values of K_{DP} are not only a consequence of the backscattering phase shift but of the variation of the degree of common orientation of the hydrometeors as well.

H31A-11 0830h POSTER

Comparison of Accumulated Rainfall Using a Blended Polarimetric and NEXRAD Z-R Techniques

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Following the devastating Fort Collins flash flood in 1997, an algorithm was developed at Colorado State University (CSU) to estimate rainfall from CSU-CHILL dual-polarization radar data. The algorithm first attempts to remove ground clutter using thresholds on the correlation coefficient RHOHV and standard deviation of the total differential phase PHIDP. Specific differential phase KDP is then calculated from PHIDP. The radar data are interpolated to a Cartesian grid and rainfall estimates at each grid point are determined using an optimization procedure. The procedure picks the "best" estimate of rainfall based on measurement thresholds of KDP, ZDR, and ZH. During the summers of 2002 and 2003, a UCAR-COMET grant provided an opportunity to apply the polarimetric algorithm in a real-time environment and quantitatively evaluate the performance in comparison to the standard NWS Z-R technique on selected rainfall events in northeast Colorado. Validation of the rainfall algorithms was made using 24-hour accumulated precipitation data from the Community Collaborative Rain and Hail Study (CoCoRaHS), which includes hundreds of volunteers across northeast Colorado. Verification was also achieved with available automated rain guage data (e.g., ASOS). This study focuses on a rainfall event that occurred during the afternoon and early evening hours of 19 June 2003 in the vicinity of Denver International Airport (DIA) as well as regions south and east of DIA. Comparisons of the radar and ASOS gauge rainfall total at DIA showed that the CSU-CHILL blended algorithm was in very good agreement with the gauge total; however, the CSU-CHILL estimate using the standard NEXRAD Z-R greatly overestimated the rainfall total compared to the ASOS gauge. Ground observations at DIA and a CSU-CHILL hydrometeor identification (HID) algorithm indicated that the presence of hail in the vicinity of the DIA ASOS was the likely cause of the overestimate by the NEXRAD Z-R method. Comparisons of rainfall totals from the CoCoRaHS network within 100 km of CSU-CHILL with the radar estimates showed that the blended polarimetric algorithm provided significantly better precipitation estimates compared to the NEXRAD Z-R based on bias (0.97 vs. 0.49) and root mean square (6.3 mm vs 12.3 mm) statistics. As is often the case, the dominant method used by the blended algorithm to estimate rainfall for this event was R(ZH, ZDR), suggesting that drop shape information was an important factor in providing accurate radar rainfall totals.

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H31A-12 0830h POSTER

Assessing the Applicability of Archival Radar-Rainfall Data for Hydrologic Modeling on a Fine Spatial and Temporal Scale Across the Mississippi Basin

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The applicability of archival, long-term, high spatial and temporal resolution radar-rainfall data in hydrologic models for large catchments has not been established. Uncertainties remain regarding its accuracy at the event time scale. In order to explore this issue, an archival radar-rainfall precipitation data set produced from the National Reflectivity Composite for the GEWEX Continental-Scale International Project (GCIP) along with NEXRAD Stage III data were compared with 996 NCDC rain gages throughout the Mississippi River Basin. Statistical analysis of the mean-field bias was conducted on both radar-rainfall data sets with rain gage data on a hourly scale from January 1996 to December 2000. Determination of the bias between radar and gage data focused on factors such as season, event size and duration, and distance from gage to nearest radar. These analyses will help reveal the spatial/temporal distribution of the estimation error in the different radar data sources and will improve our understanding of the applicability of archival radar-rainfall data in hydrologic modeling.

H31A-13 0830h POSTER

Filtering-out Raingauge Representativeness Errors from Radar-Rainfall Verification Statistics Based on Radar-Raingauge Samples

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Large differences between area-averaged rainfall and point raingauge measurements pose major difficulties in conclusive verification of the radar-rainfall (RR) products. We summarize our investigations of two methods for filtering-out the raingauge representativeness errors from the radar-raingauge comparisons. The first method, called the error variance separation (EVS), has already been applied to several studies and is based on the partitioning of the variance of radar-raingauge rainfall differences into the two variances of RR and raingauge errors. We show that the major assumption of this technique, negligible covariance of the two errors, is not fulfilled. Consequently, we developed a more general method called the conditional distribution transformation (CDT). The CDT retrieves the distribution of RR and the corresponding true rainfall from a typical radar-raingauge verification sample. This bivariate distribution, called the true verification distribution (TVD), can enable application of the established distribution-oriented verification methodology to evaluate the RR products in a systematic and efficient manner. Similarly to the EVS, the CDT is also based on the rigorous geostatistical apparatus and requires additional information about the small-scale spatial rainfall variability in the data sample. We describe the CDT method and an empirical test of its validity. The tests of both the EVS and the CDT procedures are based on a large data sample from the high-density raingauge network covering the Little Washita watershed in Oklahoma. The tests demonstrate that, in contrast to the EVS, the CDT method performs with satisfactory accuracy and can considerably improve on the currently used RR verification practices.

H31A-14 0830h POSTER

An Empirically Based Error-Model for Radar Rainfall Estimates

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Mathematical modeling of the way radar rainfall (RR) approximates the physical truth is a prospective method to quantify the RR uncertainties. In this approach one can represent RR in the form of an “observation equation,” that is, as a function of the corresponding true rainfall and a random error process. The error process describes the cumulative effect of all the sources of RR uncertainties. We present the results of our work on the identification and estimation of this relationship. They are based on the Level II reflectivity data from the WSR-88D radar in Tulsa, Oklahoma, and rainfall measurements from 23 surrounding Oklahoma Mesonet raingauges. Accumulation intervals from one hour to one day were analyzed using this sample. The raingauge accumulations were used as an approximation of the true rainfall in this study. The RR error-model that we explored is factorized into a deterministic distortion, which is a function of the true rainfall, and a multiplicative random error factor that is a positively-defined random variable. The distribution of the error factor depends on the true rainfall, however, its expectation in this representation is always equal to one (all the biases are modeled by the deterministic component). With this constraint, the deterministic distortion function can be defined as the conditional mean of RR conditioned on the true rainfall. We use nonparametric regression to estimate the deterministic distortion, and the variance and quantiles of the random error factor, as functions of the true rainfall. The results show that the deterministic distortion is a nonlinear function of the true rainfall that indicates systematic overestimation of week rainfall and underestimation of strong rainfall (conditional bias). The standard deviation of the error factor is a decreasing function of the true rainfall that ranges from about 0.8 for week rainfall to about 0.3 for strong rainfall. For larger time-scales, both the deterministic distortion and the random error seem to be relatively invariant in respect to the accumulation interval.

H31A-15 0830h POSTER

Three- and Four-Dimensional High-Resolution National Radar Mosaic

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The United States National Weather Service is now implementing an architecture that facilitates the central collection and distribution of base level data in real time from 154 NEXRAD sites to National Climatic Data Center and the National Centers for Environmental Prediction. With this development, the NSSL is implementing a system that produces a national (CONUS) 3D radar mosaic grid with a 1-km horizontal resolution over 21 vertical levels and a 5-minute update cycle. The mosaic system (termed NMQ for National Mosaic for QPE) takes base level data from all available radars at any given time, performs quality control, and then combines reflectivity observations from individual radars onto a unified 3D Cartesian frame. The 3D reflectivity grid can be used for multi-sensor severe storm algorithms, regional rainfall products generation, aviation weather applications, and data assimilations for convective scale numerical weather modeling. The 3D mosaic will be upgraded to a 4D dynamically updating grid in the near future. The infrastructure of the national 3D and 4D mosaic and associated products will be presented at the conference.

H31A-16 0830h POSTER

Evaluation of the Range Correction Algorithm Using Real-Time Data from Multiple WSR-88D Sites for Improved Radar Rainfall Estimation

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The Range Correction Algorithm (RCA), which has been developed by the Office of Hydrologic Development, NOAA, National Weather Service, is designed to reduce range-dependent biases in radar precipitation estimates due to nonuniform vertical profiles of reflectivity (VPR). The RCA is currently undergoing testing and evaluation at several Weather Surveillance Radar-1988 Doppler sites prior to operational implementation in the entire network. RCA is designed to improve precipitation estimates by estimating the mean VPR over the entire radar umbrella and using the VPR to calculate and apply correction factors to raw radar precipitation estimates. RCA reduces bright band contamination at near-to-mid ranges from the radar, and enhances rainfall estimates at farther ranges, where the radar beam typically intercepts frozen hydrometeors above the melting layer. Since an umbrella-wide mean VPR is generally applicable at individual locations only in stratiform precipitation events, the RCA can be used only where precipitation is predominately stratiform. Therefore a companion algorithm, the Convective Stratiform Separation Algorithm (CSSA), has been implemented in conjunction with RCA. If CSSA classifies an area as convective, no range adjustment is made within that area. A version of the RCA is run in real time for seven sites across the conterminous United States. The purpose of this evaluation is to verify that RCA consistently improves precipitation estimates in real-time conditions, and to develop guidelines for its operational use and limitations. We will present the results of radar-gauge comparisons within the test umbrellas.

H31A-17 0830h POSTER

Classification of Tropical Oceanic Precipitation Using High Altitude Aircraft Microwave and Electric Field Measurements

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A physically intuitive and computationally simple precipitation mapping algorithm has been developed for use with the airborne Advanced Microwave Precipitation Radiometer (AMPR). The algorithm is based on microwave emission and scattering properties of precipitation. Specifically, emission by liquid water allows increasing brightness temperatures at low frequencies to be interpreted as increasing rain rates. Scattering by large hydrometeors (particularly graupel and hail) causes relative minima in the brightness temperatures, with progressively larger hydrometeors scattering progressively longer wavelengths. The vigor of convection is therefore ascertained according to which wavelengths are being significantly scattered. The combination of emission and scattering information from four microwave channels is used to assign a precipitation category, which is related to the liquid rain rate, the vertical extent of precipitation, and the vigor of convection. The qualitative precipitation categories output by the passive microwave algorithm have been verified using coincident radar (ER-2 Doppler Radar - EDOP) and electric field measurements (Lightning Instrument Package - LIP). These coincident measurements can subsequently be used to quantify rain rates, hydrometeor contents, and vertical profiles that are typical for each precipitation category. This algorithm has been developed using an airborne platform. Comparisons are being made with other airborne, satellite, and ground-based radar and radiometer data. This technique shows promise both as a research tool and potentially as a real-time analysis tool, which could be applied to either traditional or uninhabited aerial vehicles.

H31A-18 0830h POSTER

A TRMM Precipitation Radar-Calibrated Passive Microwave Algorithm for Overland Rainfall Estimation

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The Tropical Rainfall Measuring Mission (TRMM) satellite carries a combination of active (Precipitation Radar, PR) and multi-channel TRMM microwave imager (TMI) sensors. These sensors advance our ability to estimate rainfall over land. Rain retrieval from PR is associated with an unprecedented accuracy. The primary aspects of PR retrieval are the precipitation classification, which is facilitated by the high vertical resolution (250 meters) reflectivity profile measurements, and an inversion algorithm controlled by a surface reference technique for path integrated attenuation and a reflectivity-to-rainfall relationship with parameters differentiated for convective and stratiform rain regimes. But is limited in terms of sampling due to the narrow PR swath width (215 km). On the other hand, TMI provides wider coverage (760 km), but its observations are associated with a more complex relationship to precipitation compared to PR (especially over land). PR rain estimates are used here for calibrating an overland TMI rain algorithm. The major objective is to investigate the regional variability in terms of the retrieval parameters and its significance to the accuracy of rain estimation. Four geographic regions consisting of Africa (AFC), Amazon (AMZ), continental US (USA), and the Ganges-Brahmaputra-Meghna (GBM) river basin in South Asia are selected. A parameter based rain algorithm is developed that includes (1) multi-channel based rain screening and convective/stratiform (C/S) classification schemes, and (2) non-linear (linear) regressions for rain rate retrieval of stratiform (convective) rain regimes. For rain rate estimation we used the 37 GHz channel for AFC, AMZ and USA regions and the 85 GHz channel for GBM region. The algorithm performance is evaluated against the latest (Version 6) TRMM-2A12 product in terms of rain detection and rain rate retrieval error statistics using PR rainfall as reference. The algorithm performs better than 2A12 V6 with the major improvement being the decrease in the retrieval error variance (correlation to PR rainfall), which is about 40% for three of the regions (USA, AFC and AMZ) and 167

H31A-19 0830h POSTER

Six Years of TRMM Precipitation Data at the GES DISC DAAC

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The Tropical Rainfall Measuring Mission (TRMM), a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA), has been acquiring data from shortly after its launch in November 1997 to the present. All TRMM data, including those from the first

and, thus far, only space-borne Precipitation Radar (PR), are archived at and distributed by the GES DISC DAAC. As of January 2004, more than six million files, with a total volume of 105 TB, of TRMM data had been distributed to thousands of users from 37 different countries around the world. With the PR, TRMM has been able to produce more accurate measurements of rainfall type, intensity, and three-dimensional distribution, all of which contribute to improved tropical cyclone forecasts and better preparation for hurricanes/typhoons, and to reduction in economic loss. TRMM data have also been widely used for climate, health, environment, agriculture, and interdisciplinary research and applications. The TRMM six-year precipitation climatology is a benchmark for other tropical rainfall measurement, and for estimating tropical contributions to global water and energy cycles. As a data information and services center, the GES DISC DAAC has consistently been providing customer-focused support to the TRMM user community. These include (1) TRMM Data Search and Order System (http://lake.nascom.nasa.gov/data/dataset/TRMM/); (2) online documentation; (3) TRMM HDF Data Read Software (ftp://lake.nascom.nasa.gov/software/trmm_software/Read_HDF/); (4) TRMM Online Visualization and Analysis System (TOVAS, http://lake.nascom.nasa.gov/tovas/); and (5) TRMM data mining (http://daac.gsfc.nasa.gov/hydrology/hd_datamin_intro.shtml).

H31A-20 0830h POSTER

Detecting Climate Variability in Tropical Rainfall

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A number of satellite and merged satellite/in-situ rainfall products have been developed extending as far back as 1979. While the availability of global rainfall data covering over two decades and encompassing two major El Niño events is a valuable resource for a variety of climate studies, significant differences exist between many of these products. Unfortunately, issues such as availability often determine the use of a product for a given application instead of an understanding of the strengths and weaknesses of the various products. Significant efforts have been made to address the impact of sparse sampling by satellite sensors of variable rainfall processes by merging various satellite and in-situ rainfall products. These combine high spatial and temporal frequency satellite infrared data with higher quality passive microwave observations and rain gauge observations. Combining such an approach with spatial and temporal averaging of the data can reduce the large random errors inherent in satellite rainfall estimates to very small levels. Unfortunately, systematic biases can and do result in artificial climate signals due to the underconstrained nature of the rainfall retrieval problem. Because all satellite retrieval algorithms make assumptions regarding the cloud structure and microphysical properties, systematic changes in these assumed parameters between regions and/or times results in regional and/or temporal biases in the rainfall estimates. These biases tend to be relatively small compared to random errors in the retrieval, however, when random errors are reduced through spatial and temporal averaging for climate applications, they become the dominant source of error. Whether or not such biases impact the results for climate studies is very much dependent on the application. For example, all of the existing satellite rainfall products capture the increased rainfall in the east Pacific associated with El Niño, however, the resulting tropical response to El Niño is substantially smaller due to decreased rainfall in the west Pacific partially canceling increases in the central and east Pacific. These differences are not limited to the long-term merged rainfall products using infrared data, but are also exist in state-of-the-art rainfall retrievals from the active and passive microwave sensors on board the Tropical Rainfall Measuring Mission (TRMM). For example, large differences exist in the response of tropical mean rainfall retrieved from the TRMM microwave imager (TMI) 2A12 algorithm and the precipitation radar (PR) 2A25 algorithm to the 1997/98 El Niño. To assist scientists attempting to wade through the vast array of climate rainfall products currently available, and to help them determine whether systematic biases in these rainfall products impact the conclusions of a given study, we have developed a Climate Rainfall Data Center (CRDC). The CRDC web site (rain.atmos.colostate.edu/CRDC) provides climate researchers information on the various rainfall datasets available as well as access to experts in the field of satellite rainfall retrievals to assist them in the appropriate selection and use of climate rainfall products.

URL: http://rain.atmos.colostate.edu/CRDC

H31A-21 0830h POSTER

Validation and Analysis Studies With TRMM Precipitation Data

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This poster will summarize results from a number of studies of TRMM precipitation data. The topics to be presented include: 1) validation of TRMM precipitation retrievals using rain gauges on ocean buoys; 2) error estimates for TRMM precipitation retrievals and dependence on space and time averaging; 3) analysis of the diurnal cycle of precipitation in TRMM and rain gauge data and comparison with simulations by the NCAR Community Climate Model Version 3 (CCM3), including confidence limits on the amplitude and phase of the diurnal and semidiurnal harmonics; 4) analysis of the annual cycle in TRMM precipitation data and comparison with CCM3; and 5) detection of tropical wave modes in TRMM precipitation and OLR data by space-time spectral analysis.

URL: http://csrp.tamu.edu/bowman/

H31A-22 0830h POSTER

Estimating Confidence Levels for Detection of Diurnal and Weekly Cycles in TRMM Rainfall

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The Tropical Rainfall Measuring Mission (TRMM) satellite is in a low-inclination orbit that causes it to visit regions at varying local times over a period of about 1.5 months. It is therefore able in principle to detect changes in rainfall statistics with time of day (the diurnal cycle). Estimating sampling error levels in the diurnal cycle characteristics is complicated by the fact that satellite views of higher-latitude regions can be separated by only 1.5 h. Rainfall is often correlated over such time scales, and observations cannot be treated as independent. Based on experience acquired in estimating confidence intervals for monthly mean rainfall from TRMM, a method for estimating confidence levels for the amplitudes of both diurnal and weekly cycles in rainfall statistics has been developed that attempts to take into account both the varying intervals between satellite visits and the varying areal coverage of individual grid boxes. (Weekly cycles in rainfall might occur because of weekly variations in human activity and the effects of pollution on rainfall.) Results from analyzing approximately 6 years of TRMM rain estimates from the TRMM Microwave Imager (TMI) are presented for latitudes accessible to TRMM, on a 2.5° grid.

H31A-23 0830h POSTER

Sampling Simulation of Rainfall Estimation for GPM Mission Using Radar-AMeDAS Composites

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Sampling Errors of rainfall estimation by a group of eight satellites whose orbits are arbitrarily determined were estimated by using radar-AMeDAS composites data for GPM (Global Precipitation Measurement) mission. In this study, we actually simulated eight satellites' orbits, and estimated 1-30day sampling errors over 7 area sizes ($0.1^\circ \times 0.1^\circ, 0.3^\circ \times 0.3^\circ, 0.5^\circ \times 0.5^\circ, 0.7^\circ \times 0.7^\circ, 1^\circ \times 1^\circ, 2^\circ \times 2^\circ, 5^\circ \times 5^\circ (latitude \times longitude)$) around Japan using a 3-year time series of radar-AMeDAS composites data. It should be emphasized that we consider flight patterns of actual satellites' group, and use real rainfall data over large region and long period. If we adopt now flying five sun-synchronous-orbit (SSO) satellites (SSO5) (Aqua, ADEOS-II, DMSP-F13, F14, F15) plus two SSO satellites (sub600, sub650; sub600 is altitude 600km, swath width 1500km, and ascending time 10:30, sub650 is altitude 650km, swath width 1500km, and ascending time 16:00) as seven constellation satellites, sampling error in case of eight satellites would be estimated as $30.42 \times A^{-0.24} \times T^{-0.34} \times R^{-0.18}$(%) in case of area size 0.1-1.0 (deg.), and $29.72 \times A^{-0.41} \times T^{-0.34} \times R^{-0.19}$(%) in case of area size 1.0-5.0 (deg.). A means area size (deg.), T means integration time (days), and R means averaged rainfall rate (mm/h). In this model, monthly sampling error would be approximately 7%, and daily sampling error would be approximately 22% for averaged rainfall rate R of 5.0 mm/h over $1^\circ \times 1^\circ$ area around Japan in case of eight satellites. On the other hand, sampling error of rainfall retrieved by now flying six satellites' group loaded microwave radiometers (SSO5 plus TRMM) would be estimated as $37.79 \times A^{-0.24} \times T^{-0.37} \times R^{-0.20}$(%) in case of area size 0.1-1.0 (deg.), and $37.55 \times A^{-0.46} \times T^{-0.40} \times R^{-0.23}$(%) in case of area size 1.0-5.0 (deg.). In this model, monthly sampling error would be approximately 7%, daily sampling error would be approximately 26% for the same averaged rainfall rate R over the same area size. This means monthly sampling error in case of eight satellites would be improved by about 0% in sampling error in SSO5 plus TRMM case, and daily sampling error in case of eight satellites would be improved by about 4% in SSO5 plus TRMM case. If we change these seven constellation satellites to other seven satellites, sampling error largely changed. We consider flush visit time interval as one of the factors of sampling error. Flush visit means satellite observes entire averaging area at each visit. We made histogram of flush visit time intervals during 3 years and paid attention to the average of flush visit time interval. Sampling error compensating the influence of averaged rainfall rate R well correlated with the average of flush visit time interval. The average of flush visit time interval, integration time T, area size A, and averaged rainfall rate R would be helpful for estimating sampling error of satellite group in the areas where we couldn

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H31A-24 0830h POSTER

A Two-Dimensional Space-Time Satellite Rainfall Error Model and its Application to Land Surface Simulations

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A comprehensive Satellite Rainfall Error Model (SREM-2D) is developed that modeled the two-dimensional space-time error structure of satellite rain retrievals. The error structure is decomposed into the following components: (1) Sensor's detection structure for rain and no rain; (2) Sensor's spatial structure of detection for rain and no rain; (3) Sensor's spatial structure for rainfall retrieval, and (4) Sensor's temporal structure for the mean field retrieval error. On the basis of Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR), parameters of the error structure for Passive Microwave (PM) and Infrared (IR) sensors are derived over the Southern United States. A demonstration of the utility of SREM-2D is shown by coupling SREM-2D with the Community Land Model (CLM) over a 40000 km2 area in Oklahoma. SREM-2D is found to be a very elegant and valuable tool for formulating scientific questions related to the understanding of propagation of satellite rainfall error in land surface simulations.

URL: http://www.engr.uconn.edu/~ucwater

H31A-25 0830h POSTER

Propagation of Multi-Sensor Quantitative Precipitation Estimation Errors in Streamflow Prediction

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The availability of remotely-sensed precipitation data from radars and satellites is increasing. These observing platforms could potentially improve substantially on information available from rain gauges because of their ability to provide expanded spatial and temporal coverage. However, the quality of these new and emerging data sets needs to be examined before they are used operationally in hydrologic forecasting models. In this research, we investigate the errors in streamflow simulation when remotely-sensed precipitation estimates are used as forcing for a hydrological model. We apply a fully distributed hydrologic model to Juniata River Basin in Pennsylvania (catchment area 8687 km2) using several types of precipitation inputs including gage only, radar only, satellite only and multi sensor products such as merged gauge-radar and merged gauge-satellite. The radar estimates used in this study are hourly Digital Precipitation Arrays from the WSR-88D while the satellite estimates are hourly Hydroestimator products produced by the National Environmental Satellite, Data and Information Service. The differences between each of these products will be quantified, and streamflow errors propagated through the system will be identified.

H31A-26 0830h POSTER

Assessment of Satellite Rainfall Error Propagation in Land Surface Hydrologic Variables

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Precipitation is the most important component of a mixture of hydrologic variables and is critical to the study of water and energy cycle. In this research we study the propagation of precipitation retrieval uncertainty in the simulation of hydrologic variables and fluxes (soil moisture, runoff, latent heat etc) for different satellite retrievals, different spatial grid scales, and for varing vegetation cover. We explore three satellite rain retrievals: one based on IR-only data, a second based on combined PM and IR rain product, and a third based on a combined MW-IR and lightning data; and three spatial grid resolutions: 0.25, 0.5 and 1.0 degree. This investigation is facilitated by NCAR's offline Community Land Model (CLM) forced with in situ met data from Oklahoma Mesonet and high-resolution (0.1-degree /hourly) rain gauge-calibrated WSR-88D radar based precipitation fields. In turn, radar rainfall is replaced by the three satellite rain estimates at coarser resolution (0.25, 0.5 & 1-degree) to determine their impact on model predictions. A fundamental assumption made in this study is that CLM can adequately represent the physical land surface processes.

H31A-27 0830h POSTER

Including Model Input Uncertainty In Hydrologic Modeling

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Several methods have been developed in hydrologic modeling to estimate prediction uncertainty resulting from imprecise model parametric settings. It is realized, however, that additional sources of uncertainty may be present in model inputs (i.e., the precipitation estimates), the model structure, and in the observations of streamflow. An ensemble approach is developed in this study to estimate the total prediction uncertainty of streamflow for three events impacting the Blue River Basin in Oklahoma. The QPE SUMS precipitation algorithm produces as many as nine different estimates, each of which is derived from ground-based radar, infrared satellite data, rain gauges, or combinations. The diversity of sensors used to generate the rainfall estimates provides for the creation of a rainfall probability distribution function, which is believed to encompass the "true" rainfall. All rainfall estimates are input to the Vflo hydrologic model which employs three sensitive parameters. A combined ensemble is produced from the different rainfall estimates combined with model parameter perturbations. It is shown how simulation bounds derived from the combined input-parameter ensembles encompass observations for the cases studied. Consideration of uncertainty in the model inputs is essential for hydrologic predictions cast in a probabilistic framework.

H31B CC: 220 C-E Wednesday 0830h

Coupling Microbial Activity, Water Flow, and Solute Transport in the Subsurface II Posters *(joint with B)*

Presiding: **J E Smith,** McMaster University**; M Rockhold,** Pacific Northwest National Laboratory

H31B-01 0830h POSTER

The Presence and Dynamics of Entrapped Biogenic Gas Bubbles in Peat I: Biogeochemical Implications

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Production and emission of peat gas has attracted great interest since substantial amounts of methane (CH_4) are emitted to the atmosphere from peat soils. Many studies indicate supersaturation of methane in peat water indicating a high potential for gas bubble formation. However, observations of bubbles in peat are often only qualitatively described, and as such knowledge of the dynamics of entrapped gas bubbles in peat is still greatly limited. Using field measurements at a poor fen in central Québec, we investigated variations in production and volume of gas during the growing seasons of 2002 and 2003. Measurements made with TDR and subsurface gas collectors revealed that gas volume varied throughout the growing season. There was also a short-term temporal variability related to hydrostatic and barometric pressure changes as well as a great spatial variability. Gas collected from bubbles revealed the presence of CH_4. However, its concentration also experienced spatio-temporal variability. The presence of these bubbles has important biogeochemical implications including the development of enhanced localized CH_4 diffusive gradients, alteration of local flow paths affecting substrate delivery, and the potential episodic release of CH_4 via ebullition events. These interactions must be included in peatland models to accurately describe the hydrology and greenhouse gas emissions from these ecosystems.

H31B-02 0830h POSTER

The Presence and Dynamics of Entrapped Biogenic Gas Bubbles in Peat II: Hydrological Implications

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In peat soils, the influence of hydrology on biological processes has been recognized widely as the water table determines redox and wetness conditions and water flow paths are critical for delivery of substrate and nutrients. On the other hand, biological activity may also change the hydrological conditions significantly. In peat, the gas production (CH_4, CO_2) of decomposing bacteria causes formation of bubbles. These have a great potential to change peat hydraulic properties, compressibility and pore-water pressure distribution and hence change gradients and flow paths as well as affect the peat stress and compression. Using field measurements at a poor shallow fen in central Québec we explore the hydrological implications of bubble volume dynamics in peat. The temporal variation of hydraulic conductivity, measured with piezometers, showed good correlation with gas content at those locations where highest gas content was found, but less at other places, indicating that the clogging effect of bubbles varies and may be of different nature in different types of peat. Bubbles both clogging pores and building up pressure as they grow caused great variations of pore-water pressure in localized zones. These zones may deflect flows driven by dominating flow paths to an extent that depends on how large the zones grow. As peat soils are highly compressible, they shrink and swell because of changes in water pressure and peat buoyancy and presence of bubbles and excess pressure zones therefore complicates the description of the hydrology and traditional methods and models are therefore far from satisfactory.

H31B-03 0830h POSTER

Spatial trends of potential denitrification below the root zone in an agricultural setting, San Joaquin Valley, California, USA

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Contamination of groundwater by nitrate is a major problem worldwide. Under anaerobic conditions in the subsurface, reduction of nitrate to nitrogen gas via denitrification may mitigate the problem. Denitrification has been studied extensively in the shallow subsurface, but few studies have been done to examine the potential for denitrification below the root zone. In this study, we examined spatial trends in potential denitrification rates in the sub-root unsaturated and saturated zones. Sediment samples were collected from bore holes located in the San Joaquin Valley near Merced, California. Samples were analyzed for potential denitrification rates using acetylene block enzyme assays. Maximum denitrification rates, microbial growth, and lag coefficients were calculated by calibrating a numerical model of microbial growth and substrate consumption to the experimental data. The rate coefficients were compared to hydrologic regime, depth, grain size, and organic carbon content of the sediment samples. Preliminary results show complex spatial trends in potential denitrification rates. In samples taken from near the water table and near the ground surface, rates were comparable. In the unsaturated zone and deep saturated zone, rates were orders of magnitude lower. Variability between sites and hydrologic regimes could be explained in part by abundance of organic carbon. We speculate that limitations on microbial growth and transport by sediment properties and hydrologic regime also control the ability of subsurface microbial communities to carry out denitrification.

H31B-04 0830h POSTER

Data sufficiency analysis and assessment of uncertainty before and after detection of a leachate plume from a municipal landfill

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Groundwater contamination from municipal landfill leachate consisting of halogenated volatile organic compounds and petroleum byproducts in northeastern New York State was delineated between 1993 and 1995 and has been undergoing remediation since 1998. Elevated concentrations of leachate indicators (i.e. BOD5, TSS, chloride, and Specific Conductance) were identified in several downgradient monitoring wells as early as 1986. This case study involves a statistical power analysis for the landfill's detection and monitoring wells for two distinct time periods: (1) prior to plume delineation with limited data, and (2) post construction of monitoring wells and examination of additional exploratory borings. Traditional multivariate and geostatistical techniques (cokriging) were combined with a sufficiency analysis and uncertainty assessment to evaluate the importance of multiple data types at monitoring well locations. We address whether a sufficient number of monitoring locations existed to determine, within a particular confidence interval, that a regulatory concentration was not exceeded at specified spatial locations; whether