U13A-03 1400h

A multi-scale statistical parameterization of radiative transfer in discontinuous vegetation canopies

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It has long been recognized that standard radiative transfer formulations for continuous media are not appropriate for characterizing the radiance field within and above natural vegetation. This problem is often manifested in the "hotspot effect" where the probability of an incident and exitant direction of a photon interacting with a canopy volume is correlated. The most common approach to deal with this effect is to adjust the scattering phase function. However, there are two problems with this solution: 1. Gaps exists over a range of scales so the adjustment must take into account correlations between directions due to gaps at all scales and not just the leaf scale. 2. Vegetation elements are in general non-randomly dispersed at a given scale so the parameterization of the location of vegetation elements must include clumping at potentially all scales. We present a vegetation radiative transfer model based on a multi-scale statistical parameterization of vegetation structure. The concept of the conditional gap probability function is introduced to deal with the hotspot effect. The model is compared to both measurements of below canopy gap size distributions and above canopy BRDF over BOREAS tower

U13A-04 1415h

Characterizing Woody Vegetation Spectral and Structural Parameters with a 3-D Scene Model

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Quantification of structural and biophysical parameters of woody vegetation is of great significance in understanding vegetation condition, dynamics and functionality. Such information over a landscape scale is crucial for global and regional land cover characterization, global carbon-cycle research, forest resource inventories, and fire fuel estimation. While great efforts and progress have been made in mapping general land cover types over large area, at present, the ability to quantify regional woody vegetation structural and biophysical parameters is limited. One approach to address this research issue is through an integration of physically based 3-D scene model with multiangle and multispectral remote sensing data and in-situ measurements. The first step of this work is to model woody vegetation structure and its radiation regime using a physically based 3-D scene model and field data, before a robust operational algorithm can be developed for retrieval of important woody vegetation structural/biophysical parameters. In this study, we use an advanced 3-D scene model recently developed by Qin and Gerstl (2000), based on L-systems and radiosity theories. This 3-D scene model has been successfully applied to semi-arid shrubland to study structure and radiation regime at a regional scale. We apply this 3-D scene model to a more complicated and heterogeneous forest environment dominated by deciduous and coniferous trees. The data used in this study are from a field campaign conducted by NASA in a portion of the Superior National Forest (SNF) near Ely, Minnesota during the summers of 1983 and 1984, and supplement data collected during our revisit to the same area of SNF in summer of 2003. The model is first validated with reflectance measurements at different scales (ground observations, helicopter, aircraft, and satellite). Then its ability to characterize the structural and spectral parameters of the forest scene is evaluated. Based on the results from this study and the current multi-spectral and multi-angular satellite data (MODIS, MISR), a robust retrieval system to estimate woody vegetation structural/biophysical parameters is proposed.

U13A-05 1430h

Evaluation of the Effect of Tree Shape and Density on the Correlation Between an Anisotropy Index and the Vegetation Clumping Index

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This paper presents results of model parameter testing required for the global application of a methodology that proven applicable in the Canadian environment. The Four-Scale model represents a four kernel model to simulate the anisotropy of forested environments. Its accuracy in simulating the maximum (Hotspot) and the minimum (Darkspot) of reflectance in the backscattering and forward scattering along the principal plane has allowed the formulation of the Normalised Difference of Hotspot and Darkspot (NDHD). This angular index has been shown to correlate with the vegetation clumping index, that describes the deviation of foliage distribution from a Poisson based random distribution. The clumping of vegetation significantly affects carbon budget models because it allows the correction of effective LAI observed from single angle measurements. Additional tree crown shapes have been included, and vegetation density variations within and between ecosystems are investigated. The results are evaluated in terms of model applicability to global derivation of the clumping index using POLDER data from ADEOS-1.

U13A-06 1445h

Characterization of Spatial Heterogeneity and Structure at Landscape Scale

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The monitoring of land surface dynamic processes at global scale, such as primary production, carbon and water fluxes, requires high temporal frequency remote sensing observations. Because of technological constraints, the sensors are characterized by coarse spatial resolution, i.e. a resolution from few hundred meters (MERIS/ENVISAT, MODIS/TERRA) up to one or few kilometres (VEGETATION/SPOT, SEVIRI/MSG). However, the scenes observed at this range of scales, present spatial heterogeneity which may have a great influence on land surface characteristic estimation from remotely sensed data. Therefore the characterisation of spatial heterogeneity is an important concern to scale non linear land surface processes. The aim of this study is to discuss a geostatistical approach based on two complementary tools to characterize spatial structure of remote sensing data at the landscape scale. The high spatial resolution NDVI (vegetation index) of SPOT/HRV images (20m resolution) is used to characterize the ground spatial structure of different landscapes. These NDVI images are then aggregated in order to describe the evolution of their structure with the spatial resolution. A classical method consists in describing the image spatial heterogeneity by a geostatistic tool: the variogram. The interest of the variogram is that it jointly allows to model the spatial distribution of a scene as well as to quantify the spatial heterogeneity as a function of the spatial resolution. A typology of spatial heterogeneity is derived from the variogram model parameters computed over several types of landscapes. To account for the availability of multiple wavebands, a multivariate description of the spatial heterogeneity could also be proposed. A first limit of the variogram approach is the assumption of spatial stationarity, necessary for modelling the variogram. Spatial stationarity can be checked by: - Dividing the image into local windows and adjusting the corresponding variogram model parameters for a range of window size. - Computing the variogram on increasing size of the same scene. A second limit of the variogram approach is that different models of spatial random fields can share the same variogram function. This is for example the case of the Gaussian random field with an exponential variogram and the mosaic model with Poisson random polyhedra. We show that these two models and their linear mixture are undistinguishable if the histogram and the variogram are the only tools used for characterizing the heterogeneity. In this work we propose to use the first order variogram to discriminate between these two models. Moreover, we show that it is possible to model a wide range of landscapes as a mixture of these models and to estimate their parameters and the proportion of the mixture. This new way of characterization of landscape spatial structure and heterogeneity is discussed with possible application to land surface characteristic estimation from coarse resolution observations. Key Words: remote sensing, spatial heterogeneity, landscape, scaling, spatial resolution, variogram, spatial random field simulation, non linear process

U14A CC: 517 A Monday 1530h

Remote Observation of Earth's Atmospheric Environment: The Challenge of Spatial Complexity

Presiding: **L Di Girolamo,** University of Illinois at Urbana-Champaign**; C Bostater,** Florida Institute of Technology

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U14A-01 1530h INVITED

Intercomparison of Radiation Transfer Models in Cloud Fields and Vegetation Canopies

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The communities involved in modeling radiation transfer (RT) in cloud fields and vegetation canopies have implemented, in parallel, RT model intercomparison exercises, namely the Intercomparison of 3D Radiation Codes (I3RC) and the RAdiation transfer Model Intercomparison (RAMI). These 2 projects are now being coordinated as part of the 3DRT Working Group of the International Radiation Commission. The purpose of such intercomparison is to provide benchmark cases and solutions which will be used in the development and testing of RT models. The intercomparison exercises also help to identify existing models and their ranges of applicability. Both I3RC and RAMI protocols have been designed as a series of conditions under which the various RT models should be executed. They have been selected to represent a broad set of well-defined problems for which the solutions can be easily compared. The selection of these problems are driven by the main issues faced by these two communities and, as a consequence, the proposed experiments reflect the specificity of RT problems in both cloud fields and vegetation canopy. The main goal of the first phases of the I3RC is to evaluate the performance of a wide variety of 3D RT codes on radiative experiments of varying complexity beginning with an academic "step cloud" and proceeding to more realistic cases obtained from Large Eddy Simulation models, Millimeter Cloud Radar and inferred from Landsat. In the RAMI exercise, two major series of experiments are currently scheduled: one for so-called structurally homogeneous canopies, and the other for the structurally heterogeneous ones. The main difference between these two series lies in the hierarchy of scales that may exist depending on the degree of vegetation clumpiness. This presentation will provide a general overview of the I3RC and RAMI exercises and discuss future plans of integrating clouds, vegetation, and other inhomogeneous media.

URL: http://climate.gsfc.nasa.gov/I3RC

U14A-02 1550h

Spatial auto-correlation and its impact on understanding lidar measurements of clouds

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When radiative transfer theory is applied for understanding lidar measurements, it is usually assumed that light interacts with a spatially uncorrelated medium. In situ measurements suggest that most clouds are positively auto-correlated spatially. When light travels within a positively auto-correlated cloud system, the chance of a cloudy parcel hidden behind another cloud parcel is higher than the one for an uncorrelated system. For the same amount of cloud particles, the effective extinction optical depth of the spatially auto-correlated system is equivalent to the extinction optical depth of the correspondent spatially uncorrelated system minus the extra chance of a cloud parcel hiding behind another one. This equivalent extinction adjustment is normally made, intentionally or unintentionally, when applying radiative transfer theory while assuming no spatial auto-correlation of the medium. The radiative transfer theory works fine with this equivalent extinction adjustment if multiple scattering is unimportant in a measurement. But this equivalent uncorrelated medium adjustment introduces under-estimation of multiple scattering. The impact of the spatial auto-correlation on lidar depolarization measurement data analysis and multiple scattering assessments will be presented. This study is based on simulations made with a Monte-Carlo model of lidar measurements with full Stokes vector as well as Cloud Physics Lidar (CPL) measurements. The model calculations are accelerated with FPGA-based reconfigurable computation.

U14A-03 1605h

Influence of Small-Scale Drop Size Variability on the Estimation of Cloud Optical Properties

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Most of the existing cloud radiation models and conventional techniques of data processing assume that the mean number of drops with a given radius varies proportionally to volume. The analysis of microphysical data on liquid water drop sizes acquired during the First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE), July 1987, and the Atmosphere Radiation Measurements (ARM) Cloud Intensive Operational Period (IOP), March, 2000, shows that, for sufficiently small volumes, the number is proportional to the drop size dependent power of the volume. The drop size dependent coefficient of proportionality, or a generalized drop concentration, and the exponent are determined solely by the smallest sampling volume; they are independent of the volume drops occupy and differentiate spatial distributions of drops with different sizes. For abundant small drops ($r \leq 14\mu m$) present, the exponent is 1 as assumed in the conventional approach. However, for rarer large drops ($r > 14\mu m$), the exponents fall below unity for scales between the smallest sampling volume and a “saturation” scale. At these scales, therefore, the mean number of large drops decreases with volume at a slower rate than the conventional approach assumes, suggesting more large drops at small scales than conventional models account for; their impact is consequently underestimated. The analysis presented here indicates that depending on cloud size, the neglect of small-scale drop size variability can result in a systematic underestimation of cloud horizontal optical path.

URL: http://cybele.bu.edu/download/ms.html

U14A-04 1620h

Unbiased High Resolution 3D Aerosol Retrievals from Landsat

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Satellite monitoring of the man-made pollutants in urban/ industrial regions is important to understand the climate forcing of anthropogenic aerosols. Our ability to accurately study aerosols from space over land is generally limited to dark dense vegetation (DDV) targets. The urban regions of interest are notoriously difficult because of high inhomogeneity and contrast of surface, combined with the small size of sparsely located DDV targets. Such conditions enhance the atmospheric blurring of satellite images otherwise known as 3D adjacency effect. Importantly, blurring systematically increases the apparent brightness of the dark pixels resulting in the systematic overestimation of the aerosol optical thickness over land by conventional 1D methods. The small size of the DDV targets in the urban regions defines a unique niche for Landsat-like measurements for the aerosol studies. We developed a new dark target method for unbiased simultaneous retrieval of the aerosol model and optical thickness over land, based on 3-D radiative transfer theory. We will demonstrate an application of this method for a set of ETM+ images of the Washington-Baltimore area, and its initial validation with AERONET measurements.

U14A-05 1635h

Lidar Investigation of Atmospheric Stratification: Del=2, 7/3, 23/9 or 3?

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Practically all theories of turbulence assume isotropy or at least local isotropy. In buoyancy driven flows the justification is not obvious because gravity breaks the isotropy yet acts at all scales. The classical assumption is that gravity leads to a basic stably stratified state while simultaneously postulating that the perturbations are nevertheless statistically isotropic. In the atmosphere, the scale height (about 10 km) presents a further challenge: isotropic three dimensional turbulence cannot extend to very large scales. The standard model postulates an intermediate “meso-scale gap” followed at larger scales by two dimensional horizontally isotropic turbulence. Today, although we still lack consensus about the full horizontal atmospheric statistics, the meso-scale gap separating the these D=3, D=2 regimes has not been observed and there is wide consensus that the horizontal wind is scaling in the horizontal with spectral exponent β_h =5/3 out to at least several hundred km. In the vertical direction, the spectral exponent $\beta_v > \beta_h$ implying scaling stratification with the volume of structures growing at a rate Del= $2 + (\beta_h - 1)/(\beta_v - 1)$. The two main contending proposals being $\beta_v = 11/5$ (buoyancy driven, Bolgiano-Obhukov) and β_v =3 (gravity waves, Lumley-Shur) implying Del=7/3, 23/9 respectively. In this talk we describe some recent results using state of the art lidar data of passive scalars, over the range 3m to 120km, we directly estimate Del=2.56±0.05 supporting the 23/9 dimensional “unified scaling” model . We discuss this in relation to other measurement campaigns, and also the implications for modelling the atmosphere. Finally, we show how to make multifractal models of vertical cross-sections which are very close to the data.

U14A-06 1650h

Fractal Analysis Challenges for Remote Sensing of Clouds and Other Geophysical Phenomena

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Clouds are the primary source of uncertainty in models of the weather and climate. Thus it is crucial that our overall understanding of clouds be improved, especially the radiative effects of clouds. Fractal cloud models are commonly used to investigate radiative effects caused by the spatial heterogeneity of real clouds. These complex distributions exhibit variability across a range of scales, suggesting the utility of fractal modeling as a means of simulating and exploring cloud properties. Estimation of fractal dimension, the principle parameter of fractal models, has been shown to exhibit sensitive dependence on which estimator is used, suggesting a variety of estimators must be studied to determine which gives the most accurate results. This presentation will demonstrate that fractal dimension estimation is unreliable and depends upon many factors including instrument resolution, sun-view geometry, spectral channel, averaging techniques, number of data points, and estimation algorithm used. The primary conclusion drawn from this study is that the measurement of fractal dimension cannot be achieved with confidence for clouds and other geophysical phenomena and an alternative approach must be developed in order to acquire scale invariant (fractal) properties from clouds that are input into fractal models. Thus it is necessary to develop more sophisticated fitness criteria for selecting appropriate fractal models and their corresponding parameter values.

U15A CC: 517 A Monday 1715h

Union Frontier Lectures I

Presiding: **S King,** Purdue University**;** **W R Peltier,** University of Toronto

U15A-01 1715h INVITED

Cold Regions Hydrology: Its State and Future

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The major hydrological events in cold regions are related to storage and melt of snow and ice and the related energetics of phase change. Cold regions hydrology therefore is subject to a relatively unique assemblage of hydrological processes and parameters that produce a very distinctive hydrological response. Observational networks of snowfall, snow depth, ice extent, soil frost and streamflow have never been dense in cold regions, which due to their large size and remoteness adds the particular challenges of information scarcity and large scale of application to this branch of hydrology. The difficulties of field observations of snow accumulation, interception, redistribution, frozen soil moisture content, and ice-covered streamflow in remote cold regions environments mean that even routinely-gauged basins represent subjects of high uncertainty in hydrological calibration and estimation. Uncertainty in model operation is exacerbated by the temperate-environment bias of many hydrological models, in which their underlying approach, assumptions and structure may not be suited to the dynamics of cold regions hydrology. This paper reviews recent progress in defining and describing the relevant land-based hydrological cycle in cold regions, the scaling behaviour of some cold regions processes and the observational challenges provoked by cold, remote environments. It then discusses the appropriate modelling strategy for such environments and how this might be addressed in the next generation of hydrological research in high latitudes and altitudes.

U15A-02 1800h

Scientific Results from the Mars Exploration Rover Mission

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U21A CC: 220 C-E Tuesday 0830h

Remote Observation of the Earth’s Surface and Atmosphere: The Challenges of Spatial Complexity Posters

Presiding: **S Lovejoy,** McGill University**;** **A B Davis,** Los Alamos National Laboratory

U21A-01 0830h POSTER

Optical and Radar Remote Sensing Measurements of the Extreme Flood of 2003, Indus River, Pakistan and NW India

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