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OBSERVING AND DERIVING LAND COVER PROPERTIES AND VEGETATION DYNAMICS FOR USE IN WEATHER AND CLIMATE MODELS

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1. INTRODUCTION

Global scale multi-temporal observations of land surface properties from satellites provide a wealth of information regarding the Earth's land surface properties and dynamics. Initial efforts in this domain were based on data derived from instruments such as the Advanced Very High Resolution Radiometer onboard the NOAA series of satellites, but were limited by the inadequate radiometric quality of these data. The Moderate Resolution Imaging Spectro-radiometer (MODIS) onboard NASA's Terra and Aqua spacecraft is now supplying high quality data sets that offer new information and insights regarding the spatio-temporal dynamics in land surface properties. This information can be used to improve the representation of both the static and dynamic properties of land surfaces within weather and climate models at continental to global spatial scales, and seasonal to inter-annual time scales.

In this paper, we describe efforts and recent results related to mapping and monitoring land surface properties from MODIS, emphasizing land cover and vegetation dynamics. Specifically, we describe data sets that characterize the global distribution of vegetation and land cover types. Central to these efforts is the creation of a flexible database of land cover properties. This database can be used to tailor the land cover representation to the needs of individual users or models. Below we describe the various land cover data sets that we are producing from MODIS data.

In addition, we discuss initial results from using two years of MODIS data to examine intra- and inter-annual variation in surface properties. In the former case, we discuss how MODIS data can be used to monitor continental to global scale vegetation phenology, emphasizing identification of key intra-annual transition dates such as the onset of greenup and senescence. In the latter case, we present preliminary results from change vector analysis applied to two years of MODIS data, which reveal inter-annual variation in land surface biophysical conditions associated with variations in climate forcing. The objective of this paper is not to be comprehensive, but rather to provide an overview and resource for further reading and information.

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2. LAND COVER MAPPING

The MODIS global land cover product suite (MOD12) includes two main parameters. The first parameter (MOD12Q1) provides global land cover at 1-km spatial resolution updated at roughly quarterly (96-day) intervals. Note that because land cover is largely static at this time scale, early quarterly releases represent revisions to the existing map. Subsequent releases should stabilize rapidly, and once this happens, we anticipate scaling back to annual or semi-annual updates.

In addition to the 1 km maps, the MODIS global land cover product is also being provided at coarser resolution (nominally 5 km ≈1/20 degree) to serve the needs of the global modeling community who typically require spatial resolutions much coarser than 1 km. As part of this data set, the sub-grid scale frequency distribution for each class is included to provide information regarding fine resolution spatial variability in land cover within each 1/20 degree cell. Full details regarding this product are provided in Friedl et al (2002).

The primary objective of the MODIS land cover product is to facilitate the inference of biophysical information for use in regional and global modeling studies. Thus, the specific classification units of land cover need to be both discernible with high accuracy from remotely-sensed and ancillary data, and directly related to physical characteristics of the surface, especially vegetation.

In support of these goals, the MODIS land cover product includes five primary data layers. These layers provide representations of land cover using distinct classification schemes, but which are internally consistent (i.e., a forest location is forest in all layers, etc.). The classification schemes included are (1) a 17 class IGBP layer, (2) a 14 class simplified IGBP layer, (3) a 6 class layer based on canopy structural properties (Myneni et al, 1997), and (4) a 6 class layer designed to support models of ecosystem biogeochemistry (Running et al. 1995), and (5) a 7 class layer depicting plant functional types (PFTs) in support of the NCAR community land model (Bonan et al., 2002).

3. INTRA-ANNUAL VARIATION: VEGETATION PHENOLOGY

The phenological dynamics of terrestrial eco-systems reflect the response of the Earth's biosphere to intra-annual dynamics of the Earth's climate and hydrologic regimes. Because of the synoptic coverage and repeated temporal sampling that satellite observations afford, remotely sensed data possess significant potential for monitoring vegetation dynamics at regional to global scales. Specifically, satellite vegetation index (VI) data such as the NDVI are correlated with green leaf area index (LAI), green biomass, and percent green vegetation cover. Until recently, the AVHRR provided the only source of global data for this purpose

The second parameter included in the MODIS land cover product includes two data layers designed to capture large scale variation in land surface properties at intra- and inter-annual time scales. Together, these two layers are referred to as the MODIS land cover dynamics parameter (MOD12Q2). Both layers are provided at 1-km spatial resolution.

For this work, the annual cycle of vegetation phenology inferred from remote sensing is defined by four key transition dates. These dates identify the key phenological phases of vegetation dynamics at annual time scales. These transition dates are: (1) greenup, the date of onset of photosynthetic activity; (2) maturity, the date at which plant green leaf area is maximum; (3) senescence, the date at which photosynthetic activity and green leaf area begin to rapidly decrease; and (4) dormancy, the date at which physiological activity becomes near zero. Because of the spatial, temporal, and ecological complexity of these processes, simple methods to monitor them from remote sensing have proven elusive.

Using data from MODIS we have implemented a method that fits satellite VI data to a logistic function of time. Based on this function, the four transition dates defined above can be identified. Briefly, temporal variation in satellite-derived VI data for a single growth or senescence cycle can be modeled using a function of the form:

$$y(t) = \frac{c}{1 + e^{a+bt}} + d \qquad (1)$$

where *t* is time in days, *y(t)* is the VI value at time *t*, *a* and *b* are fitting parameters, *c+d* is the maximum VI value, and *d* is the initial background VI value. Fitting MODIS VI data to this continuous function, phenological transition dates can be estimated based on inflection points in the function (i.e., change in the rate of curvature). Initial results from this approach are very promising. For more complete details, see Zhang et al. (2002).

4. INTER-ANNUAL VARIATION: CHANGE VECTOR ANALYSIS

The MODIS land cover dynamics parameter also includes a layer that measures land cover change, but at inter-annual time scales. This product employs a change-vector algorithm (Lambin and Strahler, 1994) to describe land cover change, and requires two full years of data for product generation. Note that this parameter is designed to identify areas where land surface properties exhibit change, independent of land cover (e.g., drought or inter-annual variation in biospheric response to climate forcing).

In change vector analysis, each annual multi-temporal set of indicator values is taken as a point in multi-temporal space, and points from successive years are connected by a change vector, also in multi-temporal space. The direction of the change vector quantifies the change process, while the magnitude of the change vector quantifies the amount of change. Change vectors applied to different indicators reveal different change processes or different aspects of change processes.

At the time of this writing, roughly 22 months of continuous consistently calibrated

MODIS data were available. The current production schedule calls for two full years of data to be available in November of 2002, at which time production of change vectors will be initiated. Release of this data layer to the public will begin once a complete evaluation and quality assurance has been completed.

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5. WEB SITE FOR DATA AND MORE INFORMATION:

http://geography.bu.edu/landcover/

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