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## ABSTRACT -- KEY POINTS

### BRDF/ALBEDO

- 1) The global MOD43B BRDF/Albedo products were provisionally released in February (with data starting from Day 305 (31 Oct 00)).
- 2) Newly delivered code for reprocessing the consistent year now includes a 5km coarse version of MOD43B1.
- 3) Aqua-compatible code has been delivered (both Terra and Aqua MODIS data will be combined for BRDF and albedo retrieval)
- 3) Extensive collaboration with our validation scientists continues (Drs. Liang, Privette, and Li)
- 4) Personnel contributed to 6 journal articles which were published during the period, while 2 additional papers were submitted.

### LAND COVER

- 1) Continued efforts were directed towards revising and improving the training site database. To this end, the sampling distribution was analyzed, new sites were added, and quality assurance was performed.
- 2) The global MOD12Q1 land cover product was released. The initial release was provided as a "beta" product. A revised version, updated to "provisional" status has been delivered and is due for release from the EDC DAAC in the very near future (August, 3, 2001).

3) Algorithm improvements and refinements were implemented in support of multiple classification systems and data fusion for mapping urban areas.

4) Results from land cover mapping activities were reported at several major international conferences including both IGARSS and AGU.

## TASK PROGRESS

### BRDF/ALBEDO PRODUCT

#### Personnel

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No staff changes during this period.

#### Algorithm development

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The BRDF/Albedo Product (MOD43B) (PGE23) was upgraded to a provisional status on 2 Feb 2001 with data from Day 305 (31 October 00 onward). From this date the input MOD09 Surface Reflectance was corrected for aerosol contamination. MOD43B1 (Model Parameters) was also included in this release. A series of BRDF shape factors are also included as a separate SDS in MOD43B1 to provide some measures of the anisotropy of each pixel. The code was further updated for the "consistent year" reprocessing effort (using data from 1 Nov 00 - 31 Oct 01). An additional 5km Coarse Product (MOD43B1C) was added for ease in evaluation. Adjustments were made to the overall algorithm to compensate for the limitations of the cloud mask in accurately identifying cloud shadows.

Aqua compatible code was also delivered. MYD43B will operate on combined Terra and Aqua MODIS data (thus increasing the number of looks available over a 16 day period). A second NBAR SDS will be available in MYD43B to provide NBAR at both the overpass time of Terra and at the overpass time of Aqua.

## Scientific advances

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The algorithm continues to operate consistently and reliably. NBAR results are particularly stable and interest in using this nadir surface reflectance product is increasing. NBAR is the primary input to the MOD12Q1 Land Cover Product and the reliability of this spectral product has allowed the Land Cover team to produce a provisional product with only 6 months worth of MODIS data.

The MODIS Atmosphere's Team (Dr Michael King) used our November MOD43B3 Albedo data to model a seasonal global albedo map for use as a static reference to identify deviations in atmospheric quantities. Dr Yoram Kaufman also requested coarse resolution (1 degree grid) global albedo information. The November data represent the most cloud-free period aquired thus far.

An evaluation of the albedo product for various land cover types is underway to ascertain the variance and temporal stability of the product over each surface type.

## Validation activities

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Close collaboration continues with Dr Shunlin Liang (UMD) over the BARC validation site. Comparisons with ETM derived albedo have continued with partially snow covered scenes from the Nov - Jan timeframe.

Data for the Mongu (SAFARI) site continues to be accumulated for Dr Jeff Privette (GSFC) as do data for several sites in China for Dr Xiaowen Li (BU and Beijing Normal Uiversity).

## LAND COVER PRODUCT

## Personnel

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On the whole, the personnel working on the land cover product has been stable, with the exception of a decrease in the number of graduate research assistants working on the project. Specifically, Kristin Foord graduated with her M.A. and Mutlu Ozdogan left the MODIS land cover group to work with Curtis Woodcock. Alex Lotsch, a new Ph.D. student was added to the group.

## Land Cover Database

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The emphasis of efforts related to the training site database focused on identification and filling in of gaps in the geographic and ecological sampling of global land cover captured by the database. To this end, data acquisition continued during this period, focusing on key areas including northern Eurasia, Southern Asia and India, and Africa. As part of this effort site quality assurance continued, in which alternate analysts assign site labels and attributes independently and disagreements are resolved. New Landsat-7 scenes were acquired for all of the above regions.

To assess the representativeness of the site database, the distribution of training sites was compared to the EDC Olson classification, which recognizes nearly 100 specific classes. Within each Olsen class, the number and variety of seasonal land cover regions (also from EDC) was used as an index of within-class complexity (variance). Based on this analysis a set of 40 Landsat scenes have been targeted for acquisition. In parallel with this effort, we continued efforts to build a database regarding ancillary information related to global agriculture. This class is important in support of the LAI/FPAR six-biome classification scheme, and is also a problematic class to map because of its' inherent variability.

## Algorithm Development and Coding

The land cover monthly code (MOD12M) was run successfully for the period from Day 193 (July 11, 2000), through the end of December, 2001. Output from this code was provided on DLT and the data set for this period included 10 16-day composites of nadir-BRDF-adjusted reflectances in the seven MODIS land bands, plus the VI for each period.

Using these data both beta and provisional land cover products were produced. The beta product was released in April. Based on analysis of

the beta product and interim improvements to the training site database, a provisional product was created and shipped to GSFC in June. It is currently scheduled for release on August 3, 2001.

Following on previous efforts to include ancillary information using prior probabilities we refined our methodology and the provisional product includes ancillary information available from the EDC at-launch IGBP map and existing maps of global agricultural intensity. In parallel with this effort we have been refining methods to optimally merge DMSP OLS and MODIS data to improve the depiction of urban areas in the MODIS land cover product.

Following the specification changes implemented in the previous semi-annual period, we implemented changes to the land cover classification codes to allow production of the UMD 14 class scheme, the Myneni 6-biome scheme, and the University of Montana six class scheme. These two latter schemes will directly benefit the LAI/FPAR and NPP products. The UMD and Myneni maps were included in the provisional release and Montana scheme is in development this summer. Finally, classification confidence estimates and secondary labels (the second most likely class) for the IGBP class labels have been implemented and included in the provisional product.

Operationally, the bulk of our data processing is still being performed locally, thereby reducing loads on the MODAPS system. As before, all data are read and staged locally at the PI SCF, where the classification algorithms are then applied. The MOD12Q code, which runs quarterly, then reads our classification as an input, attaches headers and metadata, and releases the product into the ECS data stream.

Following changes to the specification for our Land Cover Change Product (which has been retitled as the Land Cover Dynamics Product), we began implementation of new codes and testing of algorithms in support of extracting phenological information from MODIS data. To this end, we met with Brad Reed from EDC, and Xiaoyang Zhang is scheduled to visit EDC in August to continue this effort. As before, the change vector approach is still maintained, but awaits a first year of stable MODIS data as a basis for comparison with new observations.

Finally, a 5km coarse product (MOD12Q1C) for browse purposes produced and delivered to GSFC. This was delivered in time for the consistent year reprocessing.

## ANTICIPATED ACTIVITIES DURING THE NEXT QUARTER

### BRDF/ALBEDO

A code delivery for the CMG product is expected during the summer. This quarter degree global product contains new summary statistics based on the finer resolution outputs. We anticipate providing both an Albedo CMG and a Model Parameters CMG.

We will continue to evaluate and refine the products (particularly monitoring the reprocessed data for an update to the BRDFDB).

We will continue to aid our colleagues in field validation of the products. We will be participating in the LAI/fPAR validation campaign at Harvard Forest in August.

Presentations, posters and papers will be prepared for the IGARSS'01 in Sydney, Australia; the IGBP Global Change Open Science Conference in Amsterdam, Netherlands; and the AMS Satellite Meteorology Conference in Madison, WI. Abstracts will also be submitted to the Fall Meeting of the AGU in San Francisco, CA.

### LAND COVER

In the next six months, we anticipate continued efforts towards refining and improving the training site database. This effort is scheduled to be completed by the end of September, 2001, at which point the effort in this area will be reduced to routine maintenance and updates. The major task facing the land cover effort in the fall will be production of a global land cover product based on a full year of consistent data. The availability of this data set will provide the foundation for rigorous evaluation of the quality and accuracy of the land cover maps being produced from MODIS. We also anticipate continued participation at major meetings including both the EOS-IWG in Austin, Texas and the AGU in San Francisco.

## PUBLICATION/PRESENTATION ACTIVITY

### BRDF/ALBEDO

\* A paper describing the LiTransit kernel was published in Remote Sensing Reviews for a special issue on the International Workshop on Multi-angular Measurements and Models (IWMMM-2), Ispra, Italy, 15-17 Sept, 1999.

Gao, F., X. Li, A.H. Strahler and C. Schaaf, Evaluation of the LiTransit Kernel for BRDF Modeling, Remote Sensing Reviews, 19, 205-224, 2001.

\* A paper describing the nomenclature used in multiangle remote sensing was published in RSR for a special issue on the International Workshop on Multi-angular Measurements and Models (IWMMM-2), Ispra, Italy, 15-17 Sept, 1999.

Martonchik, J. V., C. J. Bruegge, and A. H. Strahler, A Review of Reflectance Nomenclature Used in Remote Sensing, Remote Sensing Reviews, 19, 9-20, 2001.

\* A paper exploring techniques to retrieve albedo from limited observations was published in Remote Sensing of Environment.

Gao, F., C. Schaaf, A.H. Strahler and W. Lucht, Using a multikernel least variance approach to retrieve and evaluate albedo from limited BRDF observations, Remote Sens. Environ., 76, 57-66, 2001.

\* A paper from a related project describing archetypal BRDFs and their use in conjunction with AVHRR data was published in Journal of Climate.

Strugnell, N., and W. Lucht, Continental-scale albedo inferred from AVHRR data, land cover class and field observations of typical BRDFs, J. Climate, 14, 1360-1376, 2001.

\* A paper describing the use of magnitude inversions on a global basis was published in GRL.

Strugnell, N., W. Lucht and C. Schaaf, A global albedo data set derived from AVHRR data for use in climate simulations, Geophys. Res. Lett., 28, 191-194, 2001.

\* A paper investigating the use of a priori knowledge was published in JGR.

Li, X., F. Gao, J. Wang, and A.H. Strahler, A Priori Knowledge Accumulation and its Application to Linear BRDF Model Inversions, *J. Geophys. Res.*, D106, 11,925 - 11,935, 2001.

\* A paper making use of nadir BRDF-adjusted NDVIs to compensate for atmospheric effects that affect BRDF retrievals has been submitted to TGARS.

Gao, F., Y. Jin, X. Li, C. Schaaf, and A. H. Strahler, Bidirectional NDVI and Atmospherically Resistant BRDF Inversion for Vegetation Canopy, submitted to *Trans. Geosci. Remote Sens.*, 2001.

\* A paper describing the early results from the MODIS BRDF/Albedo algorithm has been submitted to RSE for a special issue on MODIS early science.

Schaaf, C. B., F. Gao, A. H. Strahler, W. Lucht, X. Li, T. Tsang, N. C. Strugnell, X. Zhang, Y. Jin, J.-P. Muller, P. Lewis, M. Barnsley, P. Hobson, M. Disney, G. Roberts, M. Dunderdale, C. Doll, R. d'Entremont, B. Hu, S. Liang, and J. L. Privette, First Operational BRDF, Albedo and Nadir Reflectance Products from MODIS, submitted to *Remote Sens. Environ.*, 2001.

\* A paper was published in the Proceedings of the 8th International Symposium on Physical Measurements and Signatures in Remote Sensing, in Aussois, France.

Schaaf, C., F. Gao, A. H. Strahler, W. Lucht, T. Tsang, N. C. Strugnell, X. Li, X. Zhang, J.-P. Muller, P. Lewis, M. Barnsley, P. Hobson, M. Disney, G. Roberts, M. Dunderdale, C. Doll, and S. Liang, Temporal Characteristics of the MODIS BRDF/Albedo Product, Proceedings of the 8th International Symposium on Physical Measurements and Signatures in Remote Sensing, Aussois, France, 8-12 Jan, 233-238, 2001.

\* A talk was presented at the American Geophysical Union Spring Meeting, Boston, MA, 29 May - 2 June, 2001.

Schaaf, C. , A. H. Strahler, F. Gao, W. Lucht, X. Li, J.-P. Muller, P. Lewis, M. Barnsley, P. Hobson, M. Disney, G. Roberts, M. Dunderdale, C. Doll, Land Surface Spectral Bidirectional Reflectance and Albedo from the MODerate Resolution Imaging Spectroradiometer (MODIS), (abstract).

\* Four talks or posters have been accepted for IGARSS'01 in Sydney, Australia.

Strahler, A. H., C. Justice et al., Land Science and Applications Results Overview from the First 16 Months of EOS Terra Modis Operations.

Schaaf, C. B., A. H. Strahler, F. Gao, W. Lucht, X. Li, X. Zhang, Y. Jin, E. Tsvetsinskaya, J.-P. Muller, P. Lewis, M. Barnsley, G. Roberts, C. Doll, S. Liang, and J. L. Privette, MODIS Operational Bidirectional Reflectance and Albedo Products.

Doll, C., J.-P. Muller, C. Schaaf, A. Strahler, F. Gao, Mapping Urban Landcover Using the BRDF/Albedo Product from the EOS-MODIS Instrument.

Zhang, X., J. C. F. Hodges, C. B. Schaaf, M. A. Friedl, A. H. Strahler, and F. Gao, Global Vegetation Phenology from AVHRR and MODIS Data. Global Vegetation Phenology from AVHRR and MODIS Data.

\* A poster has been accepted for the IGBP Global Change Open Science Conference in Amsterdam, Netherlands.

Schaaf, C. B., A. H. Strahler, F. Gao, W. Lucht, X. Li, X. Zhang, Y. Jin, E. Tsvetsinskaya, J.-P. Muller, P. Lewis, M. Barnsley, G. Roberts, C. Doll, S. Liang, and J. L. Privette, Operational Bidirectional Reflectance and Albedo Products from the MODerate Resolution Imaging Spectroradiometer (MODIS).

\* A poster has been accepted for the AMS Satellite Meteorology Conference.

Schaaf, C. B., F. Gao, A. H. Strahler, W. Lucht, X. Li, X. Zhang, Y. Jin, E. Tsvetsinskaya, J.-P. Muller, P. Lewis, M. Barnsley, G. Roberts, C. Doll, S. Liang, D. Roy, and Jeff Privette, Land Surface Albedo, Nadir BRDF-

Adjusted Reflectance, and BRDF Product from the MODerate Resolution Imaging Spectroradiometer (MODIS).

## LAND COVER

\* A paper on the use of boosting in decision trees to estimate classification probability was accepted for publication in TGARS.

Mclver, D.K. and M.A. Friedl 2001. Estimating pixel-scale land cover classification confidence using non-parametric machine learning methods, IEEE Transactions on Geoscience and Remote Sensing, in press.

\* A poster paper was presented at the Global Change Open Science Conference in Amsterdam.

Hodges, J., M. Friedl and A. Strahler 2001. The MODIS global land cover product: New data sets for global land surface parameterization, Global Change Open Science Conference: Challenges of a changing Earth (abstracts), July 10-13, 2001. pp. 91.

\* A paper on the status of the land cover product was presented at the spring AGU meetings.

Friedl, M.A. Mapping Global Land Cover From MODIS: New Data Sets for Global Land Surface Parameterization, EOS Transactions of the American Geophysical Union, supplement to Vol 82, no. 20, Boston, May 30, 2001.

\* A paper on boosting as used with decision trees was presented at a workshop data mining.

Mclver, D.K. and M.A. Friedl 2001. Beyond accuracy: Advantages of boosting in the classification of satellite remote sensing data for Earth science applications, First SIAM International Conference on Data Mining, Workshop on Mining Scientific Datasets, pp.37-44, April 5-7, 2001, Chicago, IL.

\* An invited paper was given at the International Colloquium on Physical Measurements and Signatures in Remote Sensing.

M.A. Friedl, D. McIver, J.C.F. Hodges, X. Zhang, S. Gopal, C.E. Woodcock and A.H. Strahler 2001. Land Cover Mapping from MODIS: First Results and Future Directions, 8th International Colloquium on Physical Measurements and Signatures in Remote Sensing, Aussois, France, Jan 8-12, 2001. pp. 3-8.

\* One oral and two poster presentations were made at the International Geoscience and Remote Sensing Symposium in Sydney in July.

Friedl, M. A., McIver, D. K., Zhang, X. Y., Hodges, J. C. F., Schneider, A., Baccini, A., Strahler, A. H., Cooper, A., Gao, F., Schaaf, C., and Liu, W., 2001, Global land cover classification results from MODIS, Proc. Int. Geosci. Remote Sens. Symp. 2001, Sydney, Australia, July 9-13, 2001, 3 pp.

Schneider, A., McIver, D. K., Friedl, M. A., and Strahler, A. H., 2001, Classification of urban areas at continental scales using remotely sensed data, Proc. Int. Geosci. Remote Sens. Symp. 2001, Sydney, Australia, July 9-13, 2001, 3 pp.

Zhang, Xiaoyang., Hodges, J. C. F., Schaaf, C. B., Friedl, M. A., Strahler, A. H., and Gao, F., 2001, Global vegetation phenology from AVHRR and MODIS data, , Proc. Int. Geosci. Remote Sens. Symp. 2001, Sydney, Australia, July 9-13, 2001, 3 pp.