

TYPE OF REPORT: Semiannual

TIME PERIOD: Jan - Jun, 2002

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CONTRACT NUMBER: NAS5-31369

ABSTRACT -- KEY POINTS

BRDF/ALBEDO

- 1) First Aqua images were received and a demonstration of a combined Terra plus Aqua albedo product was prepared.
- 2) Code was delivered for 1/20th degree versions of the Climate Modeling Grid (CMG) products (MOD43C1 and MOD43C2). An update to the 1-km code was also delivered to routinely provide BRDF parameters from the RossThickLiTransit nonreciprocal BRDF model as well as the current RossThickLiSparse reciprocal BRDF model
- 3) Quarter-degree albedo products from 2000-2001 were prepared for inclusion on the sample MODIS products CD.
- 4) Excellent comparisons between the 2001 MODIS albedo data and tower data from the SurfRad sites were achieved, resulting in an upgrade of the product status from "Provisional" to "Validated: Level 1".
- 5) Extensive news coverage and international requests for collaboration followed a NASA news release and the publication of an item in Nature's News and Views section highlighting the MODIS albedo results over North Africa.
- 6) Personnel contributed to 3 journal articles which were published during the period, while 3 articles were accepted for publication. Another 3 were submitted and are in review. Six presentations at professional meetings were accompanied by short papers or abstracts.

LAND COVER/LAND COVER DYNAMICS

- 1) We delivered a new land cover map product, MOD12Q1-2000289, based on 11 months of V003 data. The data included a new LAI/FPAR biome map specifically used by Ranga Myneni for the LAI/FPAR product.
- 2) We helped plan and present the MODIS Land Cover/Change Outreach Workshop, held at the University of Maryland in June.
- 3) We completed development of a prototype phenology parameter for the Land Dynamics Product and also developed a Tasselled Cap transformation of MODIS bands similar to that developed for Landsat TM bands.
- 4) We published one new journal article and submitted another journal article during the period. We made 7 presentations accompanied by short papers or abstracts at professional meetings.

TASK PROGRESS

BRDF/ALBEDO PRODUCT

Personnel

There were no changes of personnel during the period.

Algorithm development

Efforts focused on evaluating the V003 data products and performing some preliminary validation. The MOD43B Quality Flags were assessed and found to routinely provide an appropriate indication of the product quality. Albedos retrieved with the highest quality full inversion method were found to be both temporally consistent and quite accurate when compared with tower data from the SurfRad sites in the US. The albedos retrieved with the lower quality backup magnitude inversion

scheme were also found to perform quite well. Based on these efforts by Yufang Jin (who completed her dissertation work in June), the V003 products from Day 2000305 onward were declared "Validated: Level 1" in June.

Quarter-degree CMG Albedo products were composited using quality flags to provide 32-day products for inclusion in a sample MODIS products CD. CMG products at 1/20th degree were placed on an accompanying website for easy dissemination. The CMG code was updated for V004 processing to provide products routinely at this 0.05-degree resolution.

The combined Aqua + Terra Albedo/BRDF code was exercised on some early Aqua and Terra surface reflectances. Despite the use of prelaunch calibration and geolocation data in Aqua data processing, our code performed well and demonstrated the improvement expected with the additional observations available from Aqua.

Scientific advances

Dr Feng Gao devised a novel approach to quantify the vegetation structure captured by the BRDF model and presented his work at the IWMMM-3. The method is now being tested on a large amount of MODIS data.

A great deal of public interest was generated and new collaborations initiated due to our recent publications and the NASA News Release on MODIS BRDF/Albedo Products in June. The work published in Geophysical Research Letters (GRL) by Dr. Tsvetsinskaya on the albedo of North Africa was highlighted in Nature's News and Views section, and the story on "Earthshine" was subsequently picked up by a number of news organizations. A great deal of effort this spring was placed on preparing customized data sets for collaborators from a number of climate modeling groups (including NCAR, the DAO and the other groups working with the CCSM as well as those working with ECHAM-4 at Hamburg, Jena, Potsdam and ETH). Drs. Crystal Schaaf and Elena Tsvetsinskaya attended the Common Land Model Working Group Meeting in March at NCAR. Efforts to use MODIS albedo products to improve other MODIS products

(such as the MODIS Atmosphere Group's cloud products and the MODIS land surface temperature products) were also supported.

Validation activities

Close collaboration continues with Dr. Shunlin Liang (UMD) over the BARC validation site and with Dr Mike Barnsley (UWales/Swansea) over the Barton Bendish validation site.

A collaboration on snow albedo validation was begun with Drs. Julienne Stroeve, Anne Nolan, Andrew Klein and Shulin Liang to better handle the narrow to broadband conversion of MODIS spectral albedos over pure snow surfaces.

Dr Jeff Privette (GSFC) completed processing some of the albedo data from the Mongu tower site and relayed the data to us for evaluation.

Dr. Crystal Schaaf attended the Baseline Surface Radiation Network (BSRN) meeting in May, where Dr. Jin's SurfRad comparisons (SurfRad is the US contribution of BSRN) generated a great deal of interest.

LAND COVER/LAND COVER DYNAMICS

Personnel

Graduate student Matthew Alger joined the group in late May. He will assist Amanda Cooper in managing and updating the training site database.

Products/Deliveries

In May, we delivered a new version of our 1-km global land cover product, MOD12Q2000289. The new product, termed our "consistent year" product, is based on collection 3 data from December 2000, to November, 2001, omitting June, 2001 (MODIS instrument failure). It proved superior to our provisional product, which was based on six months of

data from collections 1 and 2. The new release also featured a new LAI/FPAR biome map layer designed to fit the needs of the MODIS LAI/FPAR product. An important innovation here was the subclassification of agriculture into broadleaf crops and cereal crops using prior probabilities from databases of agricultural statistics.

We also delivered a land cover product on the CLM grid that not only identified the most common land cover type in the coarse-resolution grid cell, but also gave the exact proportion of all land cover types with the grid cell. Similarly, we delivered 1/20th degree data for the MODIS CDROM website being prepared by Eric Vermote. We also provided an African subset of the 2000289 product for the SAFARI CDROM.

Algorithm development

A major thrust in algorithm development during the reporting period was further use of ancillary data using the mechanism of prior probabilities. The decision-tree classifier output provides a set of probabilities of class membership based on the input data and training sites, and ancillary data are used to adjust those probabilities using prior knowledge. In this way, more reliable distinctions can be made between close classes, such as agriculture and nearby natural vegetation. A related thrust was continued refinement of classification scripts. We also began exploration of the use of 32-day, rather than 16-day inputs, based on compositing of the two 16-day values using quality flags. This approach reduces the number of missing values, reducing classification time and enhancing classification accuracy.

Work continued on alternative classifications, notably the six-biome scheme used by Steve Running's group at Montana for his NPP product. The problem here is to make the six-biome layer as consistent as possible with the more-detailed IGBP layer. Our approach is to map IGBP to biome classes directly whenever class definitions permit, then rework those classes where the definitions are incompatible or distinctions are not made in the IGBP scheme. We also began exploration of a layer based on plant functional type (PFT), specifically for input to Gordon Bonan's community land model (CLM), using the same strategy.

In land cover dynamics, Dr. Zhang continued his development of a global phenology product, in which logistic curves are fitted to an annual sequence of EVI values calculated from NBARs, and derivatives are used to identify onset dates of greenness, green-up, maturity, senescence, and dormancy. The product attracted much interest and attention at the MODIS Land Cover/Land Dynamics Workshop at University of Maryland. Dr. Zhang also developed a MODIS equivalent of the Tasseled Cap transformation, which is commonly applied to Landsat TM data. Early results of both efforts were presented at IGARSS 2002 in Toronto.

Training sites

Maintenance and improvement of our training site database continued. Efforts included systematic rechecking of sites with independent validation by alternative analysts and careful checking of geolocation and registration between delineation on fine-resolution Landsat imagery and coarse-resolution MODIS imagery.

Validation activities

Validation of our land cover product involves two types of information-classification of unseen training sites, and aggregation of classification confidence data. Preliminary examination of these data allowed us declare the validation status of our consistent year product as "provisional." We expect to publish accuracy statistics and an accompanying discussion on our web site by November 1. All indications are that we will award the consistent year product the status of "Validated, Level 1" at that time. We also continued our cross-comparison effort, comparing our land cover product to other global datasets and to a database of California land cover types prepared from TM data for US Forest Service use.

Outreach

In outreach activities, we helped John Townshend's group at the University of Maryland conduct a MODIS outreach workshop in June. We

presented a complete description of the land cover product and the decision tree algorithm we use to produce it. We also conducted a lab session focusing on the land cover product, how to get it, and how to use it. We will also provide a land cover/land cover dynamics presentation at the outreach workshop scheduled for the University of Montana in July.

Dr. Alan Strahler attended the GL2000 Land Cover meeting in Italy in February. He has been charged by Jeff Privette to organize an effort to define the best standards and practices for global land cover validation and intercomparison of global land cover databases. This activity, sponsored by the CEOS Cal-Val Land Products Working Group and GOFCC/GOLD, will take place in the fall.

PUBLICATION/PRESENTATION ACTIVITY

New Publications

* A paper making use of nadir BRDF-adjusted NDVIs to compensate for atmospheric effects that affect BRDF retrievals was published in IEEE TGARS.

Gao, F., Y. Jin, X. Li, C. Schaaf, and A. H. Strahler, Bidirectional NDVI and atmospherically resistant BRDF inversion for vegetation canopy, IEEE Trans. Geosci. Remote Sens., 40, 1269-1278, 2002.

* A paper exploring the temporal and spatial variation in the MODIS detected albedos of various snow covered land types was published in GRL.

Jin, Y., C. Schaaf, F Gao, X. Li, A. Strahler, X. Zeng, R. Dickinson, How does snow impact the albedo of vegetated land surfaces as analyzed with MODIS data?, Geophys. Res. Let., 29, 10.1029/2001GL014132, 2002.

* A paper exploring the variation in the MODIS detected desert albedos of North Africa and the Arabian Peninsula was published in GRL.

Tsvetsinskaya, E., C. Schaaf, F. Gao, A. Strahler, R. Dickinson, X. Zeng, W. Lucht, Relating MODIS derived surface albedo to soils and landforms over Northern Africa and the Arabian Peninsula, *Geophys. Res. Lett.*, 29, 10.1029/2001GL014096, 2002.

* This paper was subsequently highlighted in Nature's News and Views section.

Lincoln, T., African Reflections, *Nature*, V417, 603, 2002.

* A paper describing how prior probabilities are used to improve classification accuracy in the preparation of the MODIS Land Cover Product was published in RSE.

McIver, D. K. and M. A. Friedl, Using prior probabilities in decision-tree classification of remotely sensed data, *Remote Sens. Environ.*, 81, 53-261, 2002.

Papers in Press

* A paper describing the early results from the MODIS BRDF/Albedo algorithm was accepted in final form by 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, in press, *Remote Sens. Environ.*, 2002.

* A paper describing the MODIS Land Cover product was accepted in final form by RSE for a special issue on MODIS early science.

Friedl, M. A., D. K. McIver, J. C. F. Hodges, X. Zhang, D. Muchoney, A. H. Strahler, C. E. Woodcock, S. Gopal, A. Schnieder, A. Cooper, A. Baccini, F. Gao, and C. Schaaf, Global land cover from MODIS: Algorithms and early results, in press, *Remote Sens. Environ.*, 2002.

* A paper describing the early MODIS BRDF/Albedo validation results was accepted in final form by RSE for a special issue on MODIS early science.

Liang, S., H. Fang, M. Chen, C. J. Shuey, C. Walthall, C. Daughtry, J. Morisette, C. Schaaf and A. Strahler, Validating MODIS land surface reflectance and albedo products: Methods and preliminary results, in press, Remote Sens. Environ., 2002.

* A paper describing a method to combine MISR information with MODIS data to produce an improved BRDF and Albedo retrieval was accepted in final form by TGARS for a special issue on MISR early science.

Jin, Y., C. Schaaf, F. Gao, X. Li, A. Strahler, C. Bruegge, and J. Martonchik, Improving MODIS surface BRDF/Albedo retrieval with MISR multi-angle observations, submitted to Trans. Geosci. Remote Sens., 2002.

Papers Submitted

* A paper describing the use of BRDF model information to derive vegetation structural information was submitted to RSE.

Gao, F., C. B. Schaaf, A. H. Strahler, Y. Jin, and X. Li, Detecting vegetation structure using a kernel-based BRDF model, submitted to Remote Sens. Environ., August 2002.

* Two papers describing the evaluation and validation of the MODIS BRDF/Albedo product were submitted to JGR.

Jin, Y., C. B. Schaaf, C. E. Woodcock, F. Gao, X. Li, A. H. Strahler, W. Lucht, S. Liang, Consistency of MODIS surface BRDF/Albedo retrievals: 1. Algorithm performance, submitted to J. Geophys. Res., 2002.

Jin, Y., C. B. Schaaf, C. E. Woodcock, F. Gao, X. Li, A. H. Strahler, W. Lucht, S. Liang, Consistency of MODIS surface BRDF/Albedo retrievals: 2. Validation, submitted to J. Geophys. Res., 2002.

Papers Presented

* Five presentations were given at IGARSS'02 in Toronto, Canada, 24-28 June, 2002.

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, J. L. Privette, and D. Roy, Global albedo, BRDF and nadir BRDF-adjusted reflectance products from MODIS, Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS'02), Toronto, Canada, 24-28 June, 2002.

Zhang, X., C. B. Schaaf, M. A. Friedl, A. H. Strahler, F. Gao, and J. C. F. H. Hodges, MODIS tasseled cap transformation and its utility, Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS'02), Toronto, Canada, 24-28 June, 2002. vol. II, pp. 1149-1151.

Zhang, X., M. A. Friedl, C. B. Schaaf, A. H. Strahler, J. C. F. Hodges and F. Gao, Using MODIS data to study the relation between climatic spatial variability and vegetation phenology in northern high latitudes, Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS'02), Toronto, Canada, 24-28 June, 2002. vol. II, pp. 1149-1151.

Friedl, M. A. McIver, D and C. E. Brodley (Invited), Integration of domain knowledge in the form of ancillary map data into supervised classification of remotely sensed data, Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS'02), Toronto, Canada, 24-28 June, 2002, vol. II, pp. 1038-1040

Friedl, M. A., A. Strahler, X. Zhang, and J. Hodges, The MODIS land cover product: Multi-attribute mapping of global vegetation and land cover properties from time series MODIS data, Proceedings of the

International Geoscience and Remote Sensing Symposium (IGARSS'02),
Toronto, Canada, 24-28 June, 2002, vol. IV, pp. 3199-3201.

* A paper was presented at the AMS Global Change Conference in Orlando,
Florida, 13-17 January 2002.

Tsvetsinskaya E., C. Schaaf, F. Gao, A. H. Strahler, R. Dickinson, and
X. Zeng, Improving the representation of arid regions of northern
Africa and the Arabian peninsula in climate models by incorporating
MODIS derived surface albedo, Proceeding of the 13th Symposium on
Global Change and Climate Variations, 13-17 January, Orlando, Florida,
J278-J280, 2002.

* A paper was presented at the 29th International Symposium on Remote
Sensing of Environment (ISRSE) which will be held in Buenos Aires,
Argentina, April 8-12, 2002.

Moody, E. G., S. Platnick, M. D. King, C. B. Schaaf, A global white-sky
surface albedo data set derived from Terra MODIS data, Proceedings 29th
International Symposium on Remote Sensing of the Environment, 8-12
April, Buenos Aires, Argentina, 2002.

* Two posters and a presentation were given at the (IWMMM-3) in
Steamboat Springs, Colorado, 10-12 June, 2002.

Strahler, A., C. Schaaf, 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, J. L. Privette, and D. Roy, Global land surface albedo,
nadir BRDF-adjusted reflectance and BRDF products from MODIS:2000-
present (abstract), International Workshop on Multiangular Measurements
and Models, 10-12 June, Steamboat Springs, Colorado, 2002.

Schaaf, C., F. Gao, Y. Jin, X. Zhang, A. Strahler, X. Li, W. Lucht, E.
Tsvetsinskaya, J.-P. Muller, M. Barnsley, P. Lewis, G. Roberts, C.
Doll, S. Liang, J. L. Privette, and D. Roy, Evaluation of the MODIS
albedo, nadir BRDF-adjusted reflectance and BRDF products, (abstract),
International Workshop on Multiangular Measurements and Models, 10-12
June, Steamboat Springs, Colorado, 2002.

Gao, F., X. Li, C. Schaaf, Y. Jin, X. Zhang, A. Strahler, J. Hodges and M. Friedl, Detecting land cover and land cover changes with BRDF derived features, (abstract), International Workshop on Multiangular Measurements and Models, 10-12 June, Steamboat Springs, Colorado, 2002.

* A paper was accepted for the 15th AMS Conference of Biometeorology and Aerobiology in Kansas City, Missouri, 28 Oct - 1 Nov, 2002.

Zhang, X., M. Friedl, C. Schaaf, A. Strahler, J. Hodges, and F. Gao, Mapping global vegetation phenology using 1 km MODIS data, Proceedings 15th AMS Conference of Biometeorology and Aerobiology, 28 Oct - 1 Nov, Kansas City, Missouri, 2002.

* A paper was accepted for the AMS Global Change Conference in Long Beach, California, 9-13 February, 2003.

Tsvetsinskaya, E., C. Schaaf, F. Gao, A. H. Strahler, R. Dickinson, X. Zeng and W. Lucht: Spatial variability in MODIS-derived surface albedo over global arid and semiarid regions, 14th AMS Conference on Global Change and Climate Variations, 9-13 February, Long Beach, California, 2003.

* An invited paper on decision tree classification of remotely-sensed data was presented at Interface 2002 in Montreal, Quebec, Canada, 17-19 April.

Friedl, MA. and C. E. Brodley (Invited), Supervised learning from large, high dimensional remote sensing data sets, paper presented at *Interface 2002*, April 17-19, 2002, Montreal, Quebec.

ANTICIPATED ACTIVITIES DURING THE NEXT REPORTING PERIOD

BRDF/ALBEDO

Code deliveries to support a change from ISIN to SIN grids will be delivered. Code for a 0.05 degree CMG NBAR product will also be delivered.

We will evaluate the Aqua data, and the Aqua plus Terra product, as well as the V004 reprocessed data (which will begin to flow in November).

We will continue our close collaborations with climate modeling efforts within the IDS community. We will host an outreach meeting on MODIS Radiation and Snow products at BU in October. This outreach effort will be followed by a meeting of the CEOS/WGCV Land Product Validation Subgroup on Albedo products.

The group will support a number of MODIS User Outreach workshops this summer and fall, including the Vegetation Biophysical Parameters Workshop in July and the Radiation Products Workshop in October.

LAND COVER/LAND COVER DYNAMICS

Activities will center around (1) refining our training site database, including the addition of new sites and quality control of existing sites; (2) continued exploration of 32-day, instead of 16-day inputs; (3) processing and analysis of validation statistics; (4) continued development of alternate classification schemes, including plant functional types; (5) continued development of phenological metrics; (6) new development of change vector indicators of land cover change from multiyear input data; (7) land cover validation planning for CEOS; and (8) continued support of users of land cover classification data.