Land-Cover/Land-Use Change Science Team Session at the 2011 NASA Carbon Cycle and Ecosystems Joint Science Workshop: Observations and Data for Land-Use Change with a Focus on Agriculture

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The 2011 Carbon Cycle and Ecosystems Joint Science Workshop, held from October 3-7, 2011, at the Hilton Alexandria Mark Center in Alexandria, VA, included a focus group meeting to discuss observations and data for land-use change. The one-day focus group meeting, organized by the NASA Land-Cover/Land-Use Change (LCLUC) program that took place on October 6, 2011, with over 60 participants. The meeting included presentations by LCLUC Science Team members and invited scientists, a breakout session organized for discussion of the future program focus and direction, and a poster session.

Garik Gutman [NASA Headquarters (HQ)—*LCLUC Program Manager*] opened the proceedings, presenting an overview of the LCLUC program status, discussing its current focus, and describing initiatives to shape the future of the program. Gutman highlighted the currently funded projects that address regional and global land use. He stated the necessity for *synthesis initiatives* to develop the conceptual underpinnings of LCLUC science based on funded studies during the last several years on land-cover and land-use processes, drivers, and impacts. He described particular developments related to the education and outreach initiatives of the program, including the recent research opportunity for early-career scientists to undertake LCLUC research. Gutman concluded with an overview of programmatic issues, including strengthening the social science component of LCLUC projects, the need to prioritize the science while maintaining some thematic and geographic programmatic balance, and the necessity for the program to foster the generation of global products, including a synthesis of global forest products from the Global Land Survey (GLS) projects and a new generation of global land-use products for use in integrated models.

Chris Justice [University of Maryland, College Park (UMCP)—*LCLUC Program Scientist*] followed with a review of LCLUC observations, data, and recent advances in moving from a land-cover to land-use focus. Justice noted that since its inception, 30% of the program funding has been allocated to observations, detection, monitoring, and data products. Emphasis to date has been primarily on land cover (e.g., forests and carbon), but the evolving science of global change, which addresses the impacts of climate change and adaptation, requires a broader view to include land use. With increasing human pressure on Earth's systems, the linkages between land use and food, water, and energy must be better understood. Emerging policy-relevant, integrated land-use models will need a new suite of global and regional land-use change products. Justice finished with a restatement of the meeting's purpose: *to summarize recent advances and new opportunities in land-use observations and products, and to provide an opportunity for input in terms of the program's future direction.*

LCLUC Projects

The first session of the meeting included presentations of the ongoing LCLUC projects. **Matt Hansen** [UMCP—*LCLUC Principal Investigator*] provided an update on his project titled "Advancing Methods for Global Crop Area Estimation," which is directed at estimating global soybean area using Moderate Resolution Imaging Spectroradiometer (MODIS) data, and developing a turn-key model for sub-regional/national soybean cultivation, using subpixel percent-cover training data with Landsat and RapidEye samples. Global crop-type mapping is a context-critical input to agricultural monitoring.

David Roy [South Dakota State University] presented early results from his project titled "Changing Field Sizes of the Conterminous United States: A Decennial Landsat Assessment," describing the importance of field size as an indicator of agricultural management practices such as intensification, and as a lens on the drivers of rural land-use change. Roy's analysis included applying automated object-based crop identification using multiple vegetation indices, textural features, and crop phenology to his ~100 ft resolution Web Enabled Landsat Data (WELD) product. He showed his preliminary global multi-temporal WELD product, generated in collaboration with the NASA Earth Exchange (NEX) system at NASA's Ames Research Center (ARC).

Xiaoming Xiao [University of Oklahoma (OU)] presented results from his project titled "Quantifying Changes in Agricultural Intensification and Expansion in Monsoon Asia during 2000-2010," which involves modeling cropping intensity on a global scale using MODIS surface-reflectance composites. Temporal pro-

files for individual pixels are used to derive the crop calendar and cropping intensity for a particular area. Xiao summarized the challenges posed by the identification of land cover in monsoon regions, including savannas and summer drought-affected grassland vegetation.

Kirsten de Beurs [OU] concluded the session, discussing "Land Abandonment in Russia: Understanding Recent Trends and Assessing Future Vulnerability and Adaptation to Changing Climate and Population Dynamics." De Beurs discussed the research methods and preliminary findings on land-use/land-cover change for four study regions in rural European Russia. A logistical model has been developed to link MODIS land-surface phenology estimates to Landsat-based, land-cover estimates to describe cropping intensity; individual land-owner production surveys from regional statistical offices are used to complement the model. De Beurs explained that there are several drivers with varying degrees of influence associated with agricultural abandonment and resurrection in the study region, including growth in the agricultural sector and improved productivity.

Chris Justice [University of Maryland, College Park] presented a review of LCLUC observations, data, and recent advances in moving from a land-cover to land-use focus.

Abstracts for LCLUC projects, including those mentioned above, are available on the LCLUC Program webpage at *lcluc.umd.edu/projects.php*.

LCLUC Program

The second session included several invited presentations relevant to the LCLUC program. **David Skole** [Michigan State University] described his research on carbon, agroforestry, and trees on farms for the Carbon Benefits Project: Modeling, Measurements, and Monitoring. The project combines satellite and field observations in a Web-based geographic information system (GIS) framework for carbon monitoring, reporting, and verification (MRV) purposes. The project includes use of fine-resolution (<1-m) imagery for mapping tree occurrence and crown size; field sampling, to determine biomass growth rates; and an online data management system to allow project participants to upload inventory data and perform carbon calculations to show carbon sequestration in each project area.

Steffen Fritz [International Institute for Applied Systems Analysis] stated the importance of improving the accuracy of current cropland datasets, and outlined a new Cropland Mapping Initiative in the framework of the Group on Earth Observations (GEO) Agricultural Monitoring Task to generate the best available current global cropland map. He provided a comparison of existing global land-cover products, highlighting extensive disagreement between data from MODIS, GlobCover, and Global Land Cover (GLC)-2000 with respect to cropland distribution. He described a community-driven data sharing portal, GEO-Wiki, which provides an online arena to foster data sharing, validation, and product cross-comparison. Fritz emphasized the need for a concerted international effort to provide accurate global cropland maps and change on a periodic (five-year) basis, with annual monitoring of areas undergoing rapid change.

George Hurtt [UMCP] gave a presentation on the requirements for land-use information to parameterize and calibrate global land-use models. The requirements included spatially explicit data on land-use distribution (with a spatial resolution of 0.5°), disturbance, and annual land-use transitions including wood harvest and regrowth. Hurtt explained that the next generation of terrestrial models will require improved land-use classification and subannual land-use transition data at one-hectare[1] resolution. He made several recommendations to the LCLUC community, including combining satellite-based and national inventories and separating land-use classes into multiple fractional categories; constraining model reconstructions of land use with data; and

[1] 1 hectare is 2.47 acres

generating new products that address important land-management issues, including distribution and characterization of mechanization, irrigation, and fertilizer application, to prepare for the next generation of fully integrated Earth System Models (e.g., iESMs+).

Chris Neigh [NASA's Goddard Space Flight Center (GSFC)] gave a presentation describing the new National Geospatial Agencies (NGA) commercial archive, and the GSFC fine-resolution data initiative. This initiative provides high-resolution commercial data from U.S. vendors to the NASA project investigators (PIs) in National Imagery Transit Format (NITF). Conversion to other formats and software for conversion are available upon request. Neigh stressed limitations on data sharing, but indicated that imagery or derived products could be shared with local, state, and national government and nongovernmental organizations supporting U.S. government interests, and suggested that reduced-resolution, derived products could be posted on the Website as a community resource.

Luigi Boschetti [UMCP] gave a presentation on progress towards operational, fully automated, fine-resolution mapping using a two-stage, land-cover classification system that includes a fully implemented *a priori* knowledge decision-tree classifier—the Satellite Image Automatic Mapper (SIAM) technology—and traditional techniques, including image clustering, segmentation, and supervised classification algorithms. This would result in a purely spectral, discrete, and finite six-target category land-cover classification scheme. At fine resolutions, accurate land-cover mapping can provide an analyst with information on land-use and land-management practices. Boschetti noted that the SIAM technology is capable of processing data from all calibrated multispectral sensors that have spectral bands overlapping with those of Landsat's Thematic Mapper (TM), and the number of spectral categories detected depends on the bands and the sensor. Systematic evaluation is ongoing, and successful tests have been conducted for single-date (e.g., forest/nonforest) and multitemporal applications (e.g., burned-area mapping and detection of field boundaries). Development of a single-date classifier for Landsat data and object recognition for very-high-resolution data is underway.

Breakout Sessions

The breakout sessions that followed focused on how to expand the land-use aspect of LCLUC, with questions involving the speed, direction, and focus of the program over the next 10 years, and any additional recommendations for program management. Suggestions included using ancillary data to supplement remote sensing studies including, but not limited to, models, census information, surveys, and the fusion of multi-sensor data at various temporal and spatial scales. Others recommended moving away from coarse-spatial-resolution sensors in favor of increasing sensor spatial and temporal capabilities, particularly for global analysis. Everyone acknowledged that description of land use, such as multicropping, seasonal variation, and land-cover change, requires time-series, coarse-resolution data. One suggestion included using the coarse spatial resolution that is presently available, and incorporating finer-resolution data into the analysis as such data become accessible. Some research could already benefit from recently released fine-resolution satellite data available to LCLUC Science Team members from NGA commercial archive found at *cad4nasa.gsfc.nasa.gov*.

Meeting attendees agreed that the land-use aspect of the LCLUC program should be strengthened; several priorities for such improvement were discussed. One predominant suggestion during the breakout session was to improve land-use definitions and methodological development. This may lead to the scientific community gaining a stronger understanding of the relationship between land cover and land use and the tools needed to identify associated phenomena. A clearer definition of what is really needed to conduct various LCLUC analyses could provide the framework for shaping future satellite and sensor missions and the role of the LCLUC community in land-use analysis.

Workshop Outcomes

A number of priorities for land-use science were identified, including climate impacts, vulnerability and adaptation to rapidly changing conditions, and the increasing stresses on agricultural production and water, while working towards sustainable resource use. It is also important to improve our understanding of land management to help identify issues surrounding sustainability. High-resolution data with higher temporal frequency are necessary for Integrated Assessment Models (IAM), and could be used to gain insight into patterns and processes. Continued outreach to the modeling community to obtain a more complete description of necessary inputs to drive IAMs seems warranted. The group recognized that the relevance of land-use science is increasing, and that NASA should consider increasing the LCLUC budget to enable additional or broader annual research solicitations to fulfill the needs of the growing LCLUC and modeling communities in the context of adaptation science. ■

meeting/workshop summaries

Passive Microwave Data Set Management Workshop

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A Passive Microwave Data Set Management Workshop, sponsored by NASA's Earth Science Data and Information System (ESDIS) Project, was held May 17-19, 2011, at the Global Hydrology Resource Center in Huntsville, AL. Passive microwave (PM) datasets are particularly important in the Earth Observing System Data and Information System (EOSDIS), and have been provided since the early 1970s. Over the years, widespread use of PM datasets at several different Earth science data centers has led to different approaches in documentation and levels of service.

To help rectify these differences, the main goal of the PM workshop was for data producers and distributors to review the distribution of PM data holdings across NASA's Distributed Active Archive Centers (DAACs), and to determine the extent of information available for datasets. Workshop participants representing the DAACs and NASA-funded data producers reviewed all primary (Level 1-3) PM datasets from NASA and non-NASA sensors held by the DAACs, as well as high-value datasets from other NASA-funded organizations. For the purposes of this review, datasets were categorized by discipline and instrument.

The primary objectives of the PM workshop were to:

- Identify where PM datasets are duplicated and why each specific instance of a dataset is important to a given user community;
- discuss possible changes to levels of service for some datasets; and
- discuss ways in which data providers can more clearly describe and document PM data, with the intent to harmonize semantics, formats, and documentation to the benefit of data users.

PM Workshop Findings

A full PM workshop report[1] was produced, which includes findings specific to various discipline categories such as cryospheric, land, and atmospheric datasets. Many findings were common across multiple discipline categories, and are applicable to other types of Earth science data.

General findings are listed below.

- Only a few duplicate PM datasets were identified; however, a lack of documented differences between similar datasets can cause user confusion.
- Some PM datasets are available from both the data producer and the archive-of-record. Generally, data producers make data available on a temporary basis to a smaller community, and the archive-of-record provides longer-term stewardship and broader community distribution, and may provide higher level of service.
- In several instances, information about the source data from which datasets were derived and/or the algorithm and version used was absent or not clear.
- There are significant differences in the levels of documentation among different PM datasets. In particular, these differences were found between Earth Observing System (EOS) datasets [e.g., Advanced Microwave Scanning Radiometer for EOS (AMSR-E) and TRMM Microwave Imager (TMI) datasets] and others, such as Special Sensor Microwave/Imager (SSM/I) and Special Sensor Microwave Imager/Sounder (SSMIS) datasets.
- While ESDIS does provide guidelines for dataset documentation, the guidelines are not consistently applied.
- Several datasets are readily available that have been or will be superseded by newer datasets, often located at the same data center or producer site.

PM Workshop Recommendations

The PM Workshop Committee assembled high-level recommendations in collaboration with the other attendees. It is likely that the recommendations apply to datasets from other types of instruments and/or other disciplines, as well. The full set of recommendations in the workshop report is organized by data center in order to facilitate review by the relevant DAAC User Working Groups. The high-level recommendations are as follows:

- Provide clear documentation and cross-referencing between related PM datasets. Digital Object Identifiers can help clarify whether datasets are identical.

[1] The *Report from the Passive Microwave Data Set Management Workshop* was published in December 2011 as NASA Conference Publication NASA/CP–2011-215885, and is available online at *earthdata.nasa.gov/library/2011-passive-microwave-data-set-management-workshop-report*.

- For all NASA datasets, document the lineage clearly. In particular, versions of both the dataset and the algorithm(s) need to be verified, documented, and clearly visible. Also, the source and version of the dataset(s) used as input to the product need to be identified, noting when the source data were published and especially when the version of the source data changed.

- Compile a checklist of required documentation for datasets, based on existing requirements and guidelines. Review and update documentation for PM datasets, coordinating across DAACs holding similar data.

- Develop common NASA Data Center practices for retiring superseded datasets.

PM Workshop Results

All participants—representing DAACs, data producers, and ESDIS—found this exercise to be valuable, and recommend that other instrument/discipline groups host similar workshops. Over the coming year, DAACs will present workshop findings and recommendations to their User Working Groups, and develop plans to address recommendations specific to their data holdings.

In addition to detailed recommendations, the full workshop report contains a complete list of all datasets considered (along with related tools and services), and a survey of other NASA and non-NASA PM datasets. ■

Summary of the International Year of Chemistry Symposium on Stratospheric Ozone and Climate Change

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U.S. political consensus on environmental issues is achievable.

In an era when Republican support for environmental issues is rare, the session on the Clean Air Act Amendments (CAAA) was an uplifting experience for many of the symposium participants. A presentation given by former EPA administrator, **William Reilly**, summarized the following reasons for unified, congressional support for the CAAA: clear environmental impacts of poor air quality (e.g., increased incidence of asthma); a large benefit-to-cost ratio (e.g., healthcare costs); and technologies available to support the new legislation (e.g., scrubbers for coal power plants). Similar political consensus was achieved with the Montreal Protocol, in which the ozone science was well understood and CFC alternatives were readily available.

While U.S. climate change legislation faces a divided congress, policy specialists offered several alternatives to national climate legislation, including enlargement of the existing regional cap-and-trade emissions programs and corporate involvement in international climate assessment, mitigation, and adaptation efforts. Symposium participants were reminded that scientists and policymakers view uncertainty differently. While 80% confidence is not good enough for most scientific applications, 51% confidence is motivation enough for a politician to act. That is, there is no need to have complete knowledge of the future global climate to initiate societal action.

Young scientists make a valuable contribution to the ozone-climate-policy community.

Approximately 50 young scientists presented their work in poster sessions, as well as oral presentations in a special Young Scientists' Forum held at the end of the symposium. Susan Solomon's inspiring talk will likely motivate many young scientists to pursue research careers and develop new skills, by participating in a field mission or serving on a committee of a professional society for example.

The intimate nature of the symposium facilitated interactions between young scientists and the more established members of the scientific community, many of whom made the crucial first steps in understanding the Antarctic ozone hole and stratospheric chemistry. Furthermore, the symposium introduced young scientists to several environmental career options, thanks to impressive presentations by economists, attorneys, negotiators, and administrators. ■