

**Research Opportunities in Space and Earth Sciences – 2014**  
**NNH14ZDA001N**  
**The NASA Land-Cover/Land-Use Change (LCLUC) Program, NASA Headquarters**  
**Updated August 18, 2015**

This synopsis is for the Land-Cover and Land-Use Change (LCLUC) part of the NASA Research Announcement (NRA) ROSES-2014 NNH14ZDA001N-LCLUC. This NRA offered opportunities for research to maximize the utility of current and near-future remote sensing capabilities to study LCLUC. The methods developed under this NRA round of projects will demonstrate efficient use, and seamless combination with Landsat, of satellite sensor data from international Landsat-type moderate resolution (~30 m ground resolution), multi-spectral sources on continental to global scales. NASA received 41 proposals and selected 7 proposals for a total funding of \$4.3M for three years. More details are available at: <http://nspires.nasaprs.com>.

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**Mark Friedl/Boston University**  
**Multisource Imaging of Seasonal Dynamics in Land Surface Phenology: A Fusion Approach Using Landsat and Sentinel-2**

Land surface phenology, including not only the timing of phenophase transitions but also the entire seasonal cycle of surface reflectance and vegetation indices, is important for a wide range of applications including ecosystem and agro-ecosystem modeling, monitoring the response of terrestrial ecosystems to climate variability and extreme events, crop-type discrimination, and mapping land cover, land use, and land cover change. While methods to monitor and map phenology from coarse spatial resolution instruments such as MODIS are now relatively mature, the spatial resolution of these instruments is inadequate for many applications, especially where land use and land cover vary at scales of 10's of meters. To address this need, algorithms to map phenology at moderate spatial resolution (~30 m ground resolution) using data from Landsat have recently been developed. However, the 16-day repeat cycle of Landsat presents significant challenges for monitoring seasonal variation in land surface properties in regions where changes are rapid or where cloud cover reduces the frequency of clear-sky views. The ESA/EU Sentinel-2 satellites, which will provide moderate spatial resolution data at 5-day revisit frequency near the equator and 2-3 day revisit frequency in the mid-latitudes, will alleviate this constraint in many parts of the world. Further, by combining data from Sentinel-2 and Landsat, it should become possible to monitor large areas of the Earth's land surface at frequencies that were previously not possible. The goal of the research described in this proposal is exploit the combined observational capabilities of Landsat and Sentinel-2 to develop the algorithmic, methodological, and computational basis for moderate spatial resolution monitoring of land surface phenology. Specifically, we propose to develop algorithms that will use a combination of Landsat and Sentinel-2 data to: (1) quantify the timing and magnitude of land surface phenology events ("phenometrics") at 30-m spatial resolution, and (2) generate gap-filled time series of spectral vegetation indices that characterize the entire seasonal cycle of land surface phenology at fixed time steps. To help achieve these goals, we propose to collaborate with Prof. Lars Eklundh at Lund University in Sweden, who developed the widely used

TIMESAT algorithm for estimating phenology and who is currently funded by the Swedish Space Agency to adopt TIMESAT for use with Sentinel-2. Results from this research will provide the foundation for operational production of multi-sensor land surface phenology data products at moderate spatial resolution. Further, by implementing our algorithms in TIMESAT, the proposed research will provide flexible tools that can be exploited by the user community for location- and application-specific needs.

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**Matthew Hansen/University of Maryland, College Park**  
**Integrating Landsat 7, 8 and Sentinel 2 Data in Improving Crop Type Identification and Area Estimation**

Identification of crop type and areal extent is a challenge, made difficult by the variety of cropping systems, including crop types, management practices, and field sizes. The goal of this project is to evaluate the integrated use of Landsat and Sentinel 2 data in quantifying cultivated area by major commodity crop type. The first evaluation objective is correct identification of crop type. MODIS data, due to its high image cadence, are appropriate for and have been extensively used for mapping crop. Using MODIS as a high temporal reference, an assessment of combined Landsat and Sentinel 2 observations in identifying crop type will be performed. For any given crop type, its areal extent is required in estimating production. RapidEye data represent a high temporal, high spatial resolution imaging capability over limited areas. RapidEye data will be used to evaluate area estimation of selected crop types and fine-scale agricultural landscapes using combined Landsat and Sentinel 2 data. Results will inform users of the potential value of Landsat and Sentinel 2 data to identify and map the extent of key commodity crops for a variety of landscapes, including wheat, corn and soybean.

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**Megan Lang/University of Maryland, College Park**  
**Towards Near Daily Monitoring of Inundated Areas Over North America Through Multi-Source Fusion of Optical and Radar Data**

Inundated areas, including lakes, streams, some wetlands, as well as episodically flooded areas, play important roles in many Earth system processes and provide a broad range of ecosystem services. In the meantime, they are being lost at alarming rates. However, present knowledge of the spatial and temporal dynamics of terrestrial inundation is limited. Existing surface water maps often disagree on the distribution and extent of relatively stable water bodies, and wetlands and other episodically inundated areas that are more difficult to map are among the least accurate classes in many land cover products. Further, no existing national to global scale products provide near daily, sub-hectare details on terrestrial inundation, which are critical for fully characterizing the dynamics of many inundated areas. When completed in 2017, the constellations of the European Space Agency's (ESA) Sentinel-1 and -2 together with Landsat-8 will, for the first time, provide near daily global datasets at sub-hectare spatial resolutions. The

primary goal of this study is to utilize this constellation of satellites to develop and demonstrate improved capability to monitor terrestrial inundation.

We will develop automated algorithms suitable for inundation monitoring at the global scale using Landsat-8/Sentinel-2 (L8S2) optical data and Sentinel-1 (S1) SAR data. These algorithms will be calibrated and tested extensively over study areas selected from different biomes, and will be used to generate near daily inundation products for temperate, subtropical, and tropical North America, including the United States and southern Canada. According to current launch schedules, we expect to have the data necessary to generate these products for one full year (~2017-2018) through this project. Delays in the launch of one or more of these systems will result in less than near daily coverage but will not impede the overall project.

This study responds to the LCLUC NRA by maximizing "the utility of current and near-future remote sensing capabilities" to study terrestrial inundation, a highly dynamic phenomenon that needs to be characterized at sub-hectare resolutions on a near daily basis. It provides an "efficient use and seamless combination" of L8S2 optical data and S1 SAR data for understanding global inundation dynamics. Being fully automated, the developed algorithms can be implemented in an operational system to generate global, long-term inundation records. The products derived through this study will represent multi-order improvements over existing knowledge. This study will help develop techniques to rapidly incorporate NASA-ISRO's future NISAR data into an operational inundation monitoring framework, and will benefit multiple ongoing US federal efforts, including NASA's Arctic-Boreal Vulnerability Experiment, USGS's National Water Census (<http://water.usgs.gov/watercensus/>), EPA's efforts to clarify the definition of Waters of the US under the Clean Water Act, and NOAA's Coastal Change Analysis Program.

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**David Roy/South Dakota State University**  
**Prototyping a Landsat-8 Sentinel-2 Global Burned Area Product**

This modestly budgeted proposal, with detailed proof of concept, provides an unprecedented opportunity to support the needs of several NASA programs as well as the needs of the fire science and applications communities. It is directly responsive to the primary focus of the call - developing algorithms and prototyping products for combined use of data from Landsat-8 and Sentinel-2 toward global land monitoring, and advances the virtual constellation paradigm for mid-resolution land imaging. This proposal will prototype a global burned area product by combination of Landsat-8, Sentinel-2A, and -2B data. The algorithm will be applied on a multi-temporal per-pixel basis with temporal consistency checks to reduce commission errors. Seamless integration of the different sensor data will be enabled by a random forest change regression that is parameterized with synthetic training data and that models reflective wavelength change considering the different sensor spectral response functions. In this way the algorithm can be implemented considering each sensor alone and in conjunction. Temporal consistency

checks and active fire detections derived from Landsat-8 and Sentinel-2 and contemporaneous MODIS and VIIRS active fire detections will be used to differentiate between burned areas and spectrally similar non-fire surface changes. The product will be prototyped for one fire season for all of South Africa (Year 1) and Southern Africa (Year 2) to reflect the early continental availability of Sentinel-2 data and our long standing regional experience and collaborations. Global product implementation will be demonstrated by generation of one year of global 30m Landsat-8 WELD weekly products on the NASA Earth Exchange (NEX) and using these and contemporaneous Sentinel-2 time series to produce the product at 28 globally distributed WELD tiles (Year 3). Product validation will be conducted by comparison with visually interpreted commercial high resolution data and will be endorsed by a regional network of African fire scientists and practitioners. The product will be compared with coarser resolution MODIS and VIIRS burned area products, and ESA funded, burned area products, to assess product differences and at the validation sites to quantify their relative accuracies.

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**William Salas/Applied GeoSolutions, LLC**  
**Operational Algorithms and Products for Near Real Time Maps of Rice Extent and Rice Crop Growth Stage Using Multi-Source Remote Sensing**

Rice is one of the most important crops globally for food production, supporting livelihoods, and its role in the Earth system. Rice agriculture faces major challenges in the coming decade due to increasing resource pressures, severe weather and climate change, population growth and shifting diets, and economic development. The overall goal of this proposed project is to develop integrated, seamless algorithms and operationalize multisource SAR and optical products for near real time maps of rice extent, rice calendar, and rice crop growth stage to support food security and land use decision making in South Asia. We propose to fuse moderate resolution, operational Synthetic Aperture Radar platforms (ALOS-2, Sentinel-1, RISAT-1) with Landsat 8 OLI and Sentinel-2 for mapping land use and characterizing rice agricultural conditions at 30m at national scales using a Classification And Regression Tree framework. Operationalize multisource algorithms to provide weekly maps of: near real time rice extent, rice cropping calendar and growth (phenological) stage and track risk or deviation from normal as an indicator for crop failure. We will conduct technology transfer with partners in developing regions using an open and transparent approach and grow institutional capacity to support multi-source land monitoring and food security in coordination with GEOGLAM and AsiaRice.

The Group on Earth Observations (GEO) is a coordinated effort to build the Global Earth Observation System of Systems (GEOSS). GEOSS is the leading framework to integrate Earth Observations and geospatial mapping tools to support Global Agricultural Monitoring (GLAM). NASA is a strong supporter of GEO and GEOSS and, in particular, the Agricultural task force (GEOGLAM). The next phase of the GEOGLAM plan is to begin to scale up pilot applications to have national and global monitoring tools within the next decade (fig 2). GEOGLAM was tasked to coordinate satellite monitoring

observation systems in different regions of the world in order to enhance crop production projections and support the Agricultural Market Information System (AMIS) and Crop Monitor. The objective of the Crop Monitor is to provide an international and transparent multi-source, consensus assessment of crop growing conditions, status, and agro-climatic conditions, likely to impact global production. This activity covers the four primary crop types (wheat, maize, rice, and soy) within the main agricultural producing regions. Currently, S. Asia has several gaps that are not well represented in GEOGLAM and this proposal will help fill those gaps.

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**Christopher Small/Columbia University**

**Multi-Source Imaging of Infrastructure and Urban Growth Using Landsat, Sentinel and SRTM**

The Landsat program provides more than three decades of decameter resolution multispectral observations of the growth and evolution of human settlements and development worldwide. While these changes are often easy to observe visually, accurate repeatable quantification at Landsat's resolution has proven elusive. In part, this is a consequence of the multi-scale heterogeneity and diversity of settlements worldwide. Efforts to map settlement extent are also confounded by the lack of a single, physically-based, definition of what constitutes urban, suburban, peri-urban and other types of settlement. We attempt to resolve both of these challenges by characterizing built environments in terms of their distinctive physical properties. This can be accomplished by combining multi-temporal optical reflectance with synthetic aperture radar backscatter measurements to identify combinations of physical properties that distinguish built environments from other types of land cover. Three well-known examples include an abundance of impervious surface, persistent deep shadow between buildings and high density of corner reflectors at meter to decameter scales. At optical wavelengths, spectral properties of land cover can be represented using standardized spectral endmember fractions to represent combinations of the most spectrally and functionally distinct components of land cover; soil and impervious substrates, vegetation, water and shadow. The spectral similarity of soils and impervious substrates that makes thematic classifications error prone can be resolved by using multi-season composites of spectral endmembers to distinguish spectrally stable impervious substrates from temporally variable soil reflectance resulting from seasonal changes in moisture content (thus albedo) and fractional vegetation cover. By representing the diversity of anthropogenic land use as a continuous mosaic of land cover it is possible to quantify the wide variety of human settlements in a way that is physically consistent, repeatable and scalable. We propose to develop and test algorithms to combine multi-season Landsat and Sentinel-2 optical multispectral imagery with SRTM and Sentinel-1 C-band radar backscatter imagery to produce a continuous Infrastructure Index (II) to identify and map changes in the extent of anthropogenic built environments (e.g. urban, suburban, exurban, peri-urban) worldwide between 2000 and 2015. Rather than attempting to map specific features associated with built environments (e.g. impervious surfaces, buildings, roads), we will characterize the combined optical and microwave response of a wide range of

built environments to identify the physical properties associated with these features (e.g. spectral stability, persistent shadow, anisotropic backscatter intensity). We will then use the most persistent of these properties to derive an index incorporating multiple characteristics measured by both optical and microwave sensors. The index will be calibrated using the full range of properties observed in a set of ~20 test sites spanning urban-rural gradients worldwide and vicariously validated using high spatial resolution (1-4 m) imagery and the DLR 8 m urban footprint product. As an independent comparison, we will use high resolution (sub-km) census enumerations circa 2000 and 2010 to map changes in population density associated with the mapped changes in the infrastructure index at test sites in the USA, Brazil, Portugal, Malawi, South Africa and Sri Lanka.

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**John Townshend/University of Maryland, College Park**  
**Multi-Source Imaging of Time-Serial Tree and Water Cover at Continental to Global Scales**

We propose to develop a seamless and consistent, moderate- (i.e., sub-hectare) resolution database of percent-tree and water cover on a global, epochal basis in 2000, 2005, and 2010 and continentally at annual frequency from 2010 to 2015. Globally, we will refine our existing Landsat-based maps of tree and water cover in 2000 and 2005, and we will extend these data with a global layer for 2010. Further, we will estimate tree and water cover annually from 2010 to 2015 across North and South America. All estimates will be accompanied by per-pixel estimates of uncertainty. To do so, we will generalize our proven multi-source fusion algorithms and apply them to a combination of Landsat, ALOS-PALSAR, Sentinel-2, and other data sources. This research will be partnered with the ESA-funded GLOBBIO MASS project (C. Schmullius, PI), which will map biomass regionally and globally in 2000, 2005, and 2010 epochs based on our maps of tree cover.