National Aeronautics and Space Administration

Overview of Multisource Land Imaging (MuSLI)

Jeff Masek, NASA GSFC

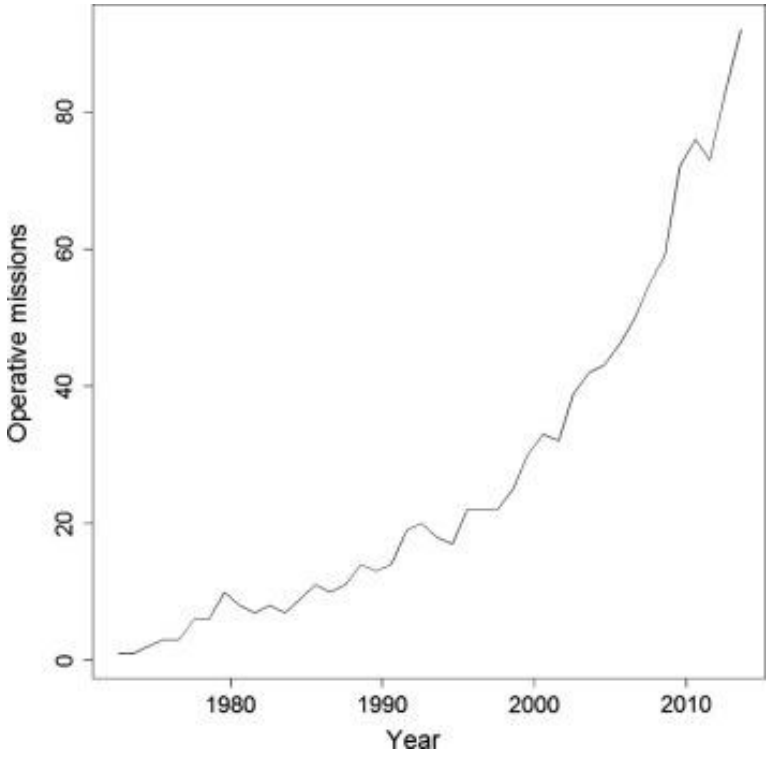
Why MuSLI?

***Supply*… In last 10 years the availability of land remote sensing data has exploded**

- Copernicus Sentinel-1 (radar), Sentinel-2 (optical) moderate resolution
- Commercial VHR imagery
- Global laser altimetry (ICESat-2, GEDI)
- Other international sources (PALSAR, VENμS, Resourcesat …)

***Demand*… The LCLUC community has expressed a clear need for**

- Dense time series observations to defeat cloud cover and explore rapidly changing land conditions (phenology, land management, surface hydrology)
- Multi-modal data sets to reveal new information about land processes



The number of near-polar orbiting, land imaging civilian satellites operational as of 1st August 1972 to 2013.

From Belward, A. and Skolen, J., ISPRS Journal of Photogrammetry and Remote Sensing, 2015

NASA MuSLI Program

- NASA Multi-Source Land Imaging (MuSLI) Team is a research program designed to advance use of multi-source remote sensing data for land monitoring
  - Originally solicited 2014 through NASA LCLUC Program
  - Re-competed in 2017, 2020

- MuSLI Objectives:
  - **Develop algorithms and prototype products** that make use of multiple satellite sources, including international and commercial data
  - Understand challenges associated with algorithms & processing streams that incorporate multiple satellite systems
  - Develop stronger community of practice among US and international (especially EU) researchers

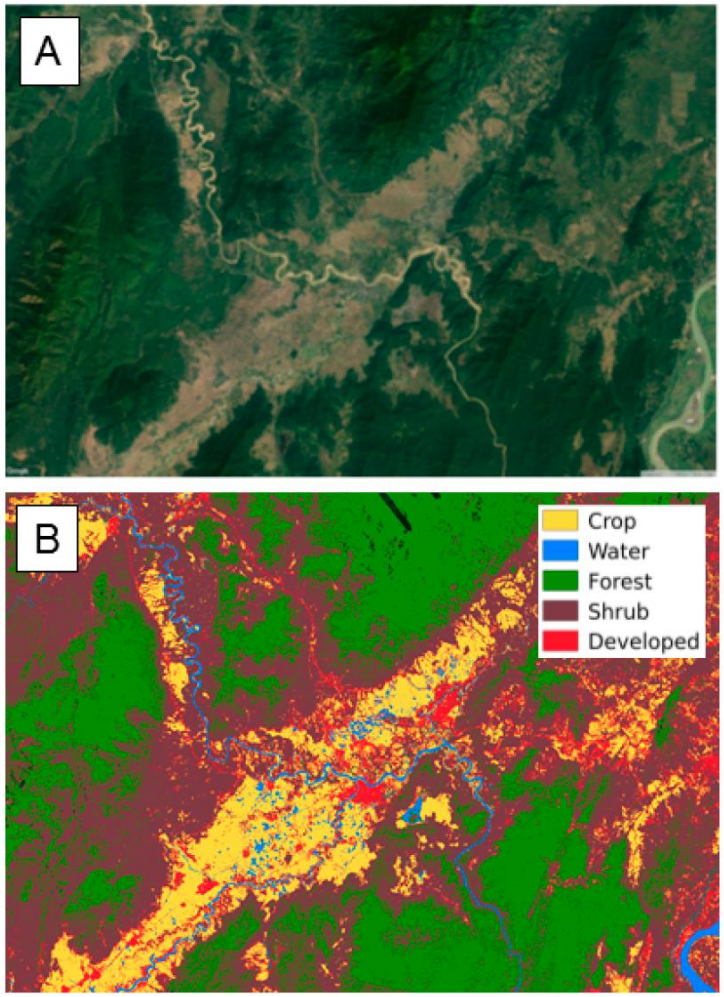
MuSLI Evolution

- Phase 1: 2015-17
  - Emphasis on combining Copernicus and Landsat data to prototype new land & coastal science products
- Phase 2: 2018-20
  - Continued emphasis on fusion of Copernicus and Landsat; mix of prototype projects (Type 2) and continental-scale datasets (Type1)
- Phase 3: 2021-23
  - Shift to focus on fusion of moderate-resolution (all sources) and VHR imagery to support LCLUC science ("Hotspots" of LU change)
  - Increased application of AI/ML fusion algorithms

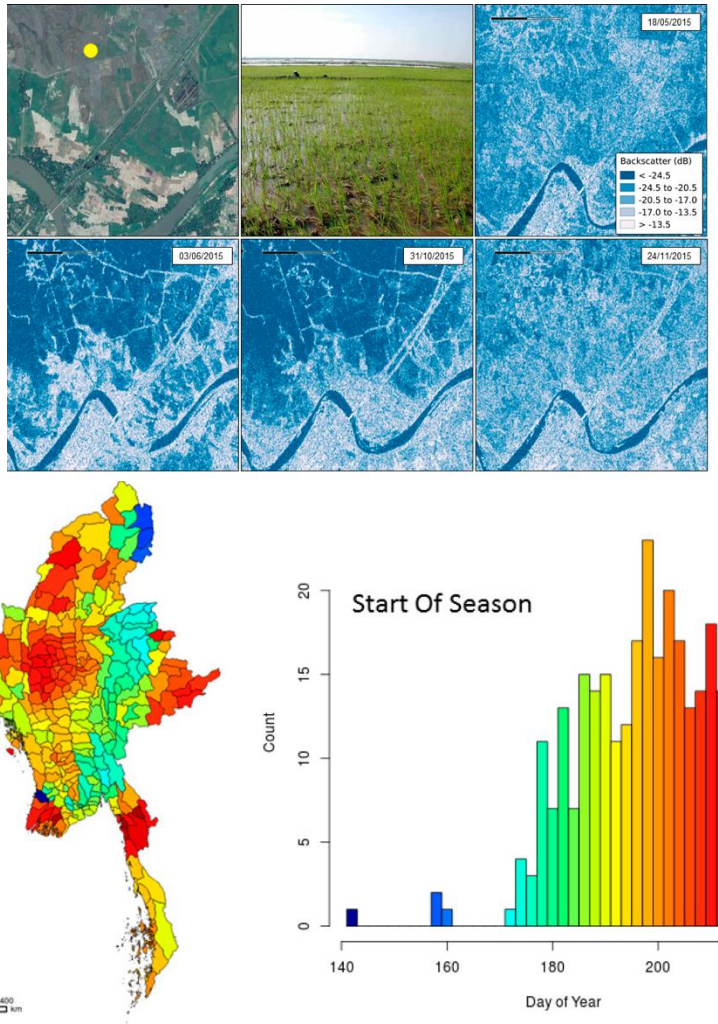
2015-17 NASA MuSLI Teams

Project Title	PI	International Collaborators
Multisource Imaging of Seasonal Dynamics in Land Surface Phenology	Friedl/BU	Eklundh / Lund
Integrating Landsat 7, 8 and Sentinel 2 Data in Improving Crop Type Identification and Area Estimation	Hansen/UMD	Defourny / Louvain
Towards Near Daily Monitoring of Inundated Areas Over North America Through Multi-Source Fusion of Optical and Radar Data	Lang / UMD	Creed / Western
Prototyping a Landsat-8/Sentinel-2 Global Burned Area Product	Roy / SDSU	Chuvieco / Alcala; Tansey / Leicester
Operational Algorithms and Products for Near Real Time Maps of Rice Extent and Rice Crop Growth Stage Using Multi-Source Remote Sensing	Salas / Applied Geosystems	Hoekman / Wageningen; Le Toan / CESBIO
Multi-Source Imaging of Infrastructure and Urban Growth Using Landsat, Sentinel and SRTM	Small / Columbia U	Esch / DLR
Multi-Source Imaging of Time-Serial Tree and Water Cover at Continental to Global Scales	Townshend / UMD	Schmullius /Jena

Combining Sentinel-1 Radar and Landsat to Map Rice Cultivation, Myanmar



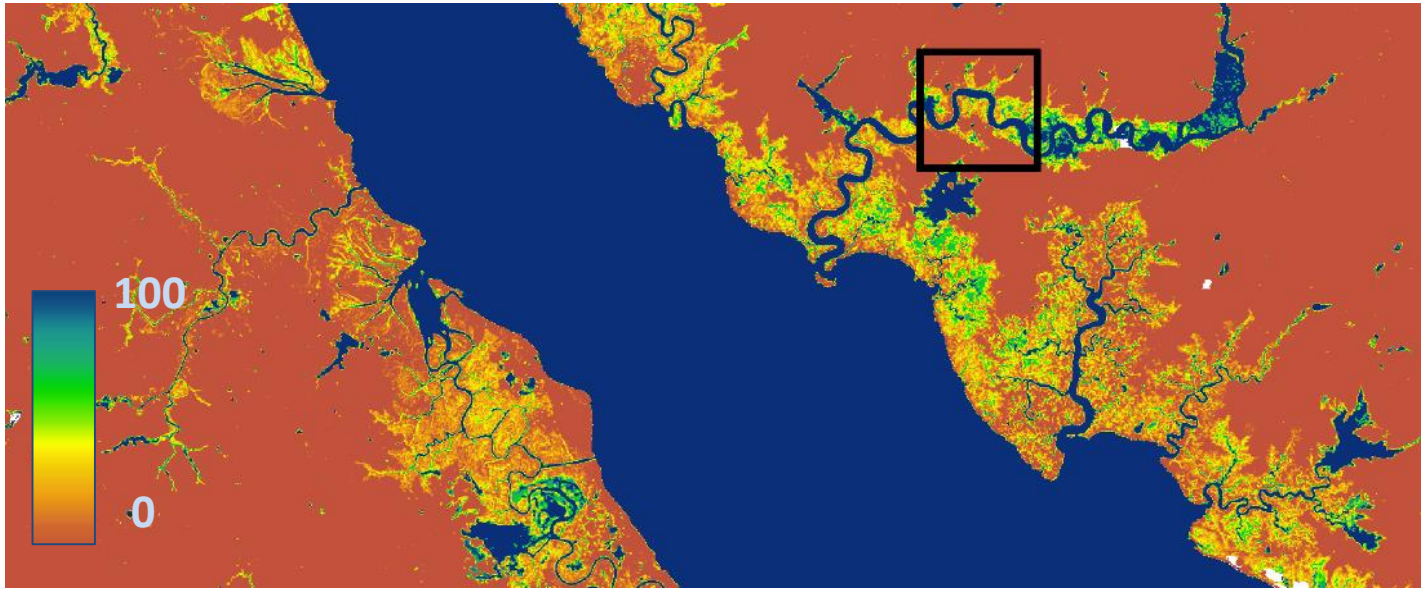
Crop Extent and Land Cover



Seasonal cycle of planting & growth stage

Torbick, N. et al., Remote Sensing, 9, 119, 2017

Fractional Surface Water from Sentinel-1 & Landsat

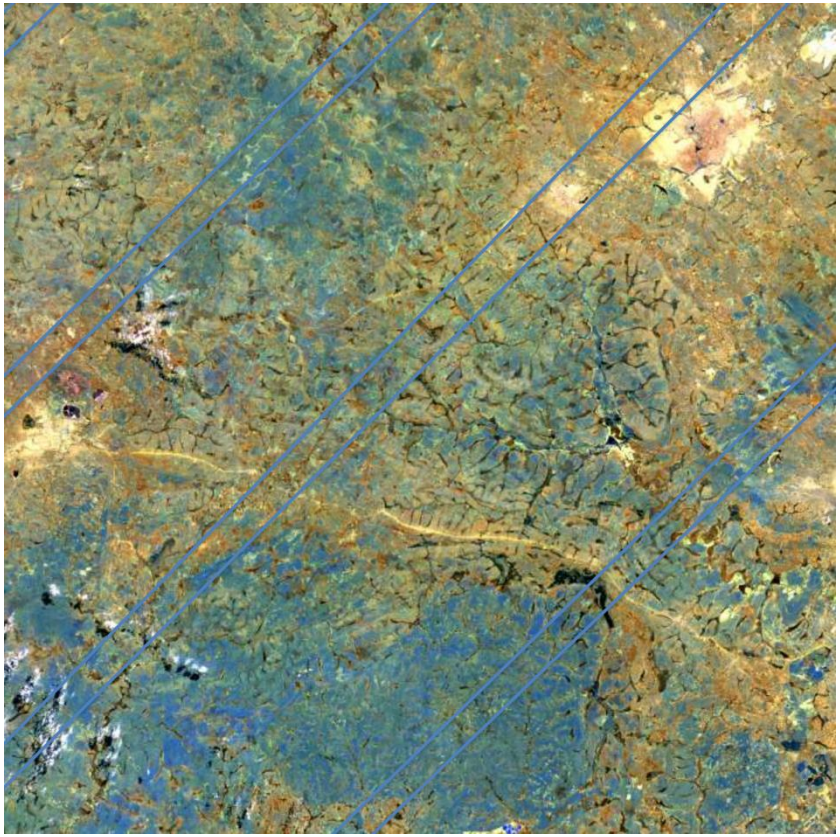


Courtesy Chengquan Huang, University of Maryland

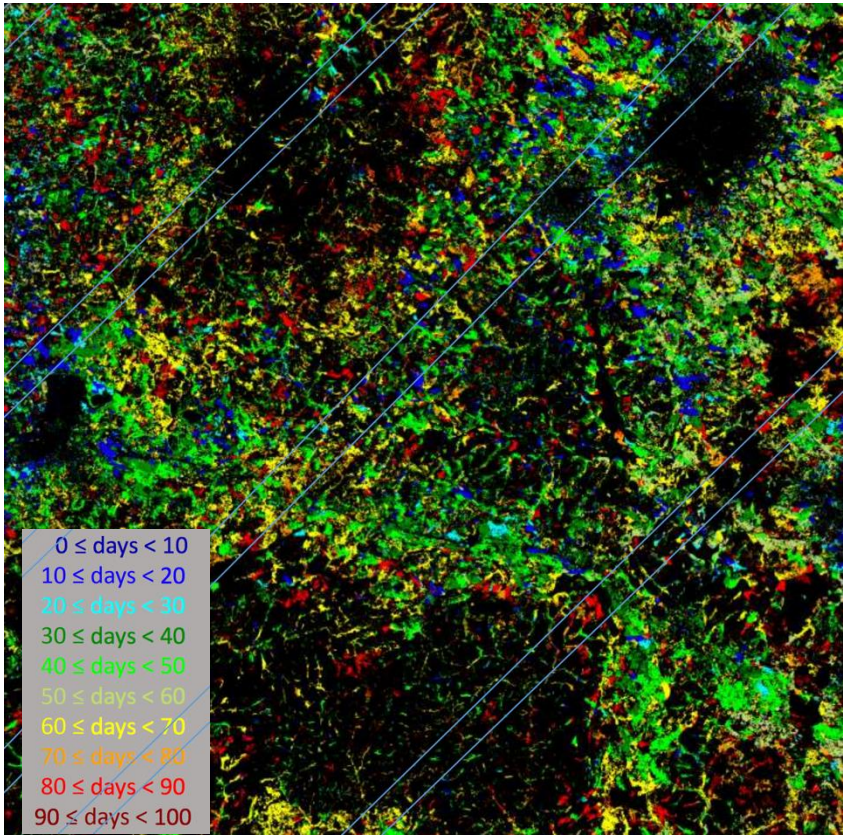
Roy/SDSU – Africa Annual Burned Area

Uses Landsat and S2 time series to map:

- timing of fires (day of year)
- (fraction burned) x (combustion completeness)



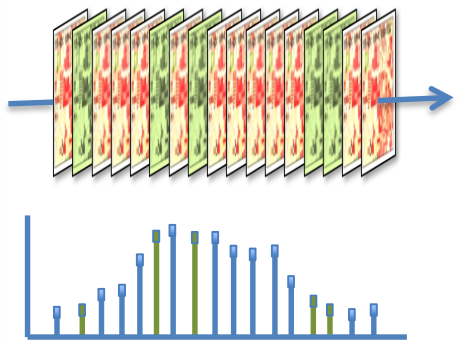
Zambia, Copperbelt Province

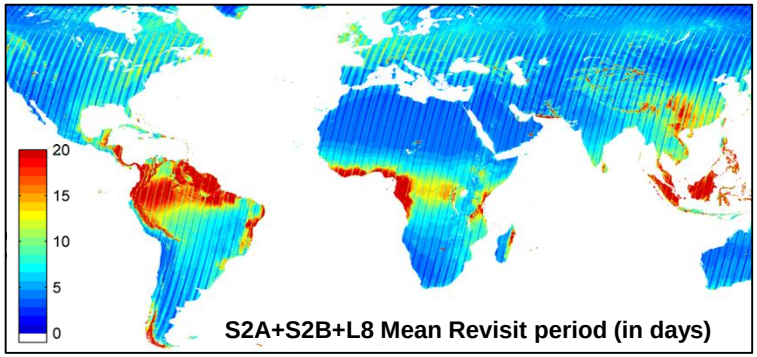


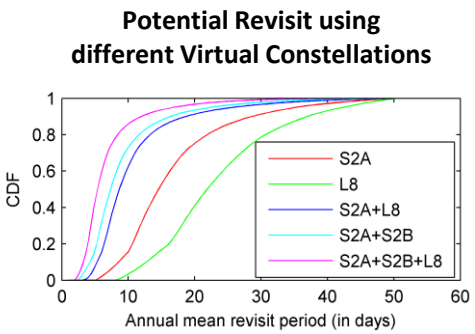
Day of Burning 2016 (minus 167)

Harmonized Landsat Sentinel-2 (HLS) Project

- Merging Sentinel-2 and Landsat data streams can provide **2-3 day global coverage**
- Goal is “seamless” near-daily 30m surface reflectance record including atmospheric corrections, spectral and BRDF adjustments, regridding
- Project is a collaboration among NASA GSFC, UMD, NASA Ames, MSFC/UAH, and LP-DAAC
- Prototype for a multi-sensor Analysis Ready Data product

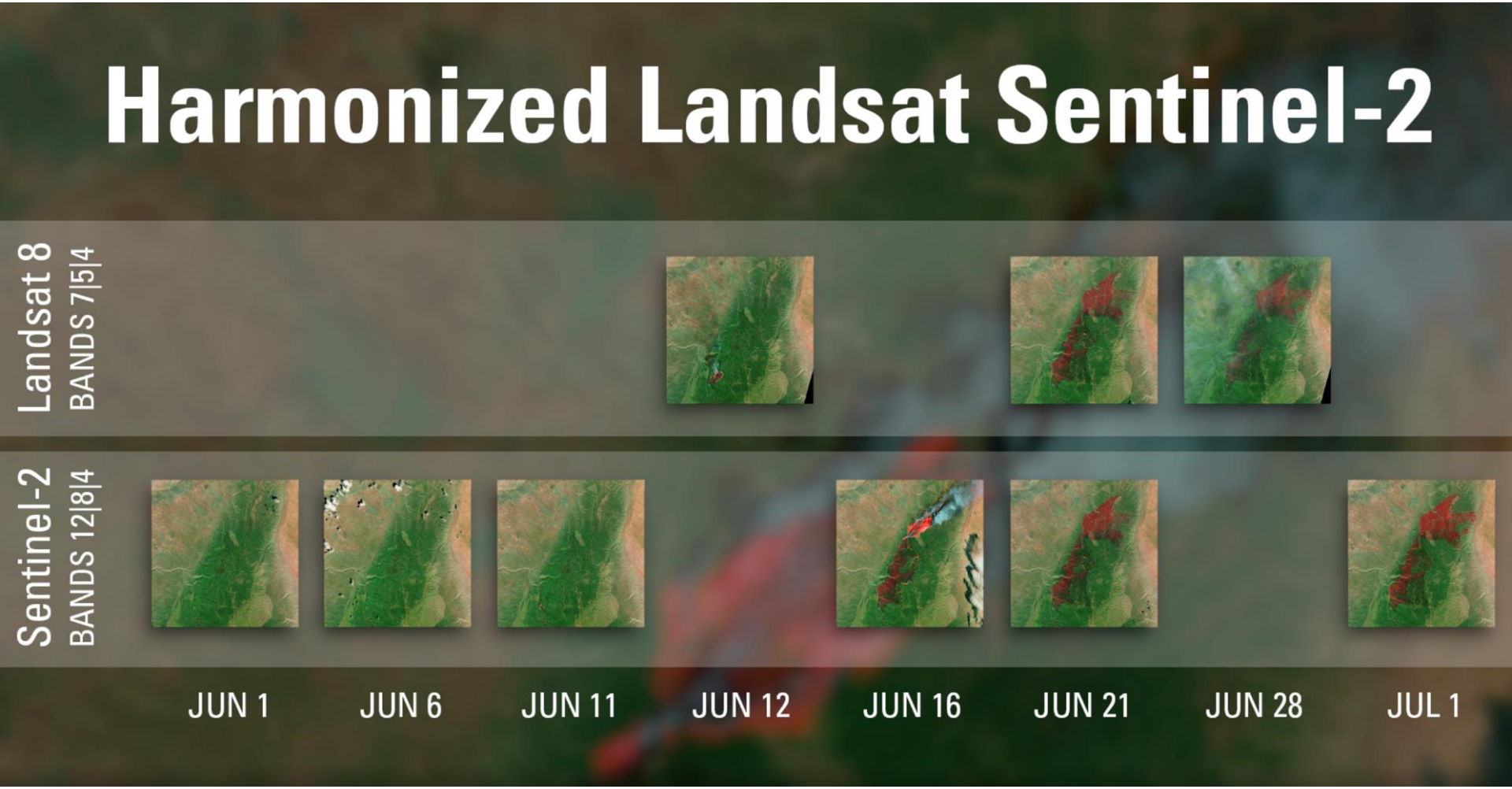






Claverie, M., Ju, J., Masek, J. G., Dungan, J. L., Vermote, E. F., Roger, J.-C., Skakun, S. V., & Justice, C. (2018). The Harmonized Landsat and Sentinel-2 surface reflectance data set. Remote Sensing of Environment, 219, 145-161.

Harmonized Landsat Sentinel-2

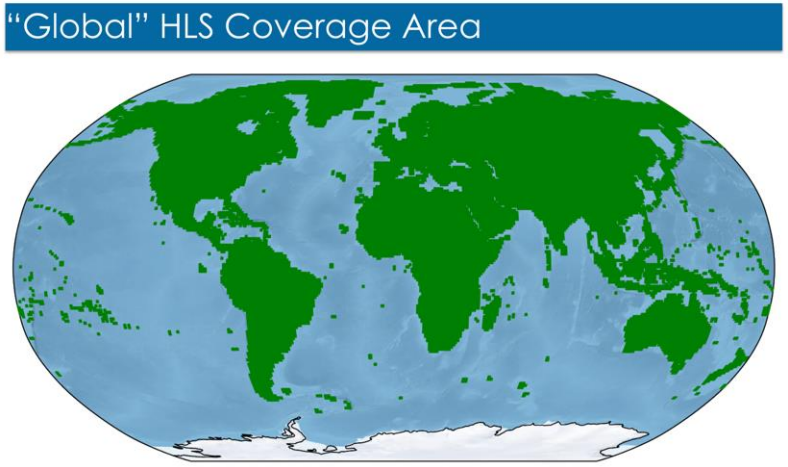


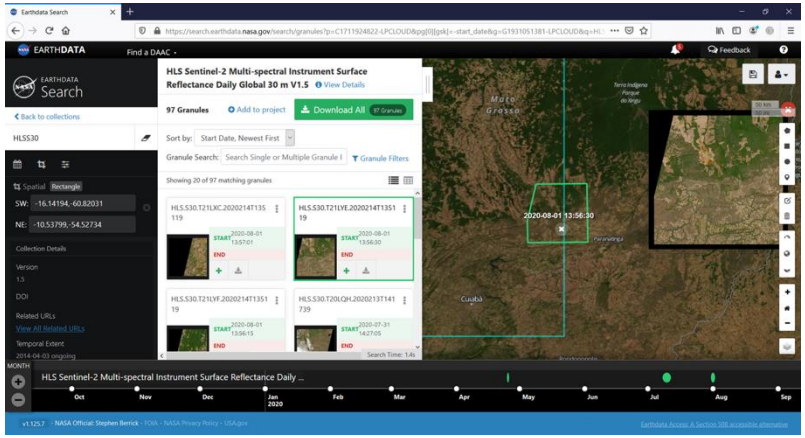
HLS Version 1.5 (Global HLS)

- Global processing via NASA MSFC IMPACT cloud computing project
  - Forward processing started October 2020 (S30 being processed now; L30 waiting for USGS Collection 2)
  - Back processing (2013 – 2020) starting winter 2020-21 (~9 months)
  - Data distribution through LP-DAAC
    - ESDIS compliant metadata, user guide, & ATBD
    - Cloud Optimized Geotiff (COG) distribution format
    - Earth Data interface for search/order
    - GIBS interface for browse
    - Stored on AWS w/ open access

- LP DAAC landing page: https://lpdaac.usgs.gov/products/hlss30v015/

- EDSC: https://search.earthdata.nasa.gov/search?q=HLS





2018-2020 MuSLI Projects

Mark Friedl (Boston U)	An Operational Multisource Land Surface Phenology Product from Landsat and Sentinel 2	
David Roy (South Dakota State U.)	Africa Burned Area Product Generation, Quality Assessment and Validation - Demonstrating a Multi-Source Land Imaging (MuSLI) Landsat-8 Sentinel-2 Capability	Type 1: Continental-scale products
Crystal Schaaf (U. Mass - Boston)	Circumpolar Albedo of Northern Lands from Landsat-8 and Sentinel-2	
Martha Anderson (USDA)	Characterizing Field-Scale Water Use, Phenology and Productivity in Agricultural Landscapes Using Multi-Sensor Data Fusion	
Petya Campbell (U. Maryland - Baltimore County)	Prototyping MuSLI canopy Chlorophyll Content for Assessment of Vegetation Function and Productivity	Type 2: Regional-scale prototypes
Glynn Hulley (JPL)	A High Spatio-Temporal Resolution Land Surface Temperature (LST) Product for Urban Environments	
Volker Radeloff (U. Wisconsin)	Monitoring Abandoned Agriculture, Fallow Fields, and Grasslands with Landsat and Sentinel-2	
Sergii Skakun (U. Maryland - College Park)	Crop Yield Assessment and Mapping by a Combined use of Landsat-8, Sentinel-2 and Sentinel-1 Images	

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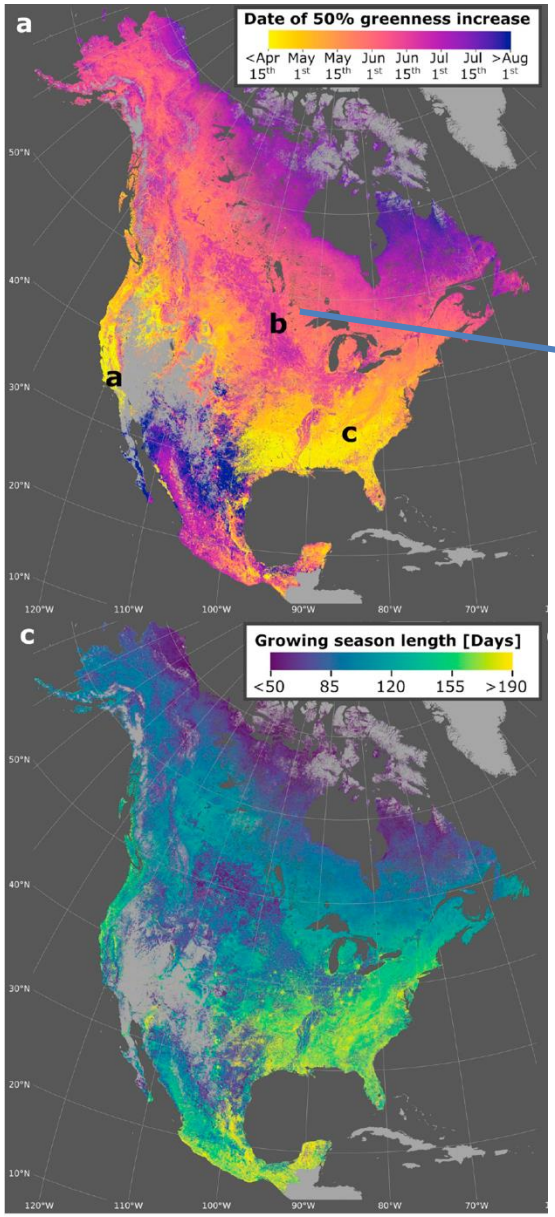
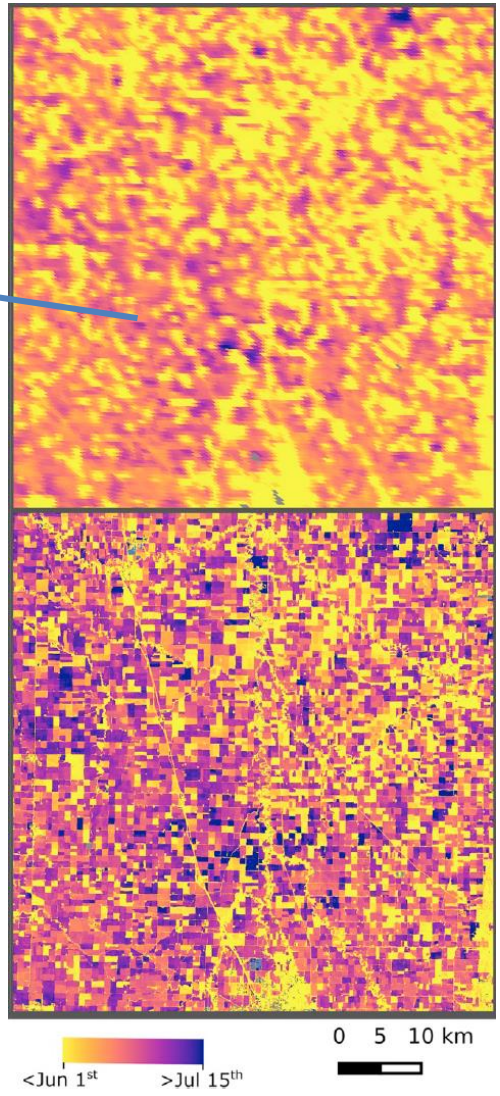
North American Phenology (Friedl, BU)

Bolten et al., Continental-scale land surface phenology from harmonized Landsat 8 and Sentinel-2 imagery, RSE, 2020





MODIS

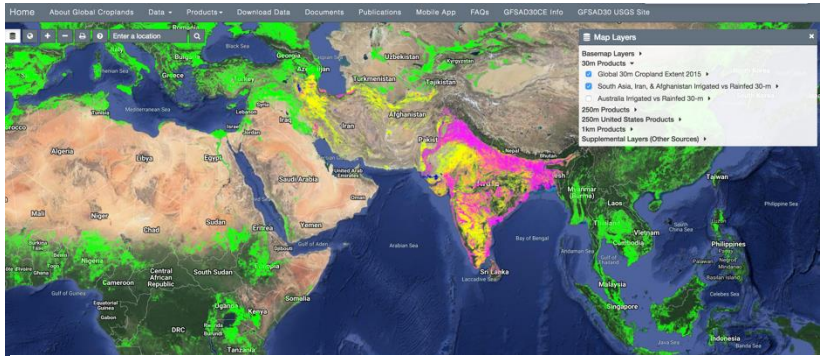
HLS (Landsat + S2)

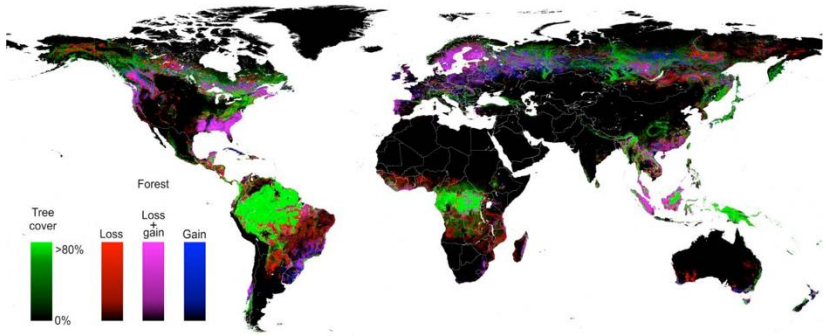
MuSLI Accomplishments

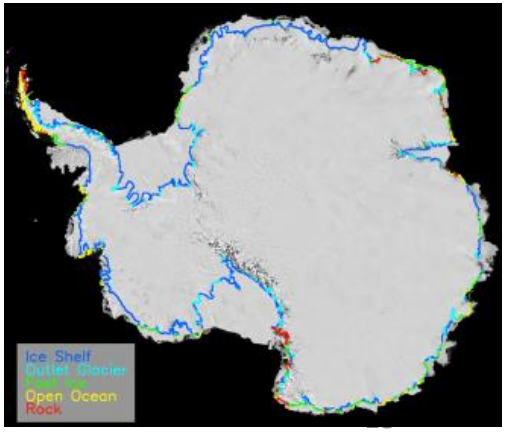
- Projects successfully developed new and improved land products via multi-source data
- US researchers gained knowledge and experience with Copernicus sensors and data sets
- MuSLI team was able to provide feedback to ESA on data quality and usability issues
  - Geolocation errors
  - Product format (filenames, granule organization, etc)
  - Importance of reprocessing & collections
- Improved collaboration with international researchers
  - International Co-I's on MuSLI Projects
  - ESA Living Planet Special Sessions 2016, 2019

Global Land Products

- Moderate-resolution counterparts to standard MODIS/VIIRS land products are *possible* and *desirable*
  - A MuSLI goal has been algorithm prototyping to support standard products
- Currently no overall NASA strategy to create these products
  - PI-driven products on GEE
  - MEASURES (PI-driven)
  - USGS Level 3 products for US from Landsat ARD
  - On-demand “recipes” via GEE, Github, Notebooks, etc.
- Recent interest from Earth Science Data Systems in continuing MuSLI Type 1 production (phenology, albedo, burned area)







MuSLI 2020 Projects (1/2)

LCLUC-20 MuSLI Selections

Sean Healey **Africa** **New PI to LCLUC**	**US Forest Service**		Sensor fusion using daily Planet imagery allows rapid deforestation monitoring in Madagascar
Volker Radeloff **Global**	**U. Wisconsin**		Global Hotspots of the Wildland-Urban Interface
Dave Skole **Africa**	**Michigan State**		Hotspot detection for monitoring new trends in carbon sequestration in systems of Trees Outside of Forests (TOF)
David Lutz **South America** **New PI to LCLUC**	**Dartmouth College**		Rapid Change from Alluvial Mining and Development in Madre de Dios, Peru: A Multi-Sensor Fusion Approach to Quantify Terrestrial and Aquatic Impacts and Test Policy Effectiveness
Alexandra Tyukavina **Global** **New PI to LCLUC**	**U. Maryland**		Multi-Resolution Quantification and Driver Assessment of Hot Spots of Global Forest Disturbance
Chris Neigh **Africa**	**NASA GSFC**		The Impact of Investment on Irrigated Rice, Dryland Agriculture and Afforestation in Senegal using SAR and Optical Time-Series Imagery in Data Fusion Approaches
Michael Keller **South America** **New PI to LCLUC**	**US Forest Service @JPL**		Quantifying agricultural expansion and tropical forest degradation in the Brazilian Arc of Deforestation: A multi-sensor, multi-scale approach

MuSLI 2020 Projects (2/2)

LCLUC-20 MuSLI Selections (cont.)

Jody Vogeler **Africa** **New PI to LCLUC**	**Colorado State U.**		The last urban frontier: Assessing drivers of urbanization and tradeoffs among social and ecosystem services associated with LCLUC in Africa
David Roy **Global**	**Michigan State U.**		Where are the missing burned areas? Global hotspots of burned area - a multiresolution analysis
Marc Simard **Global**	**JPL**		Global Hotspots of Change in Mangrove Forests
Yufang Jin **USA/California** **New PI to LCLUC**	**U. California, Davis**		Multi-source Wildland Urban Interface Characterization Enhanced with Machine Learning: Dynamics and Hazard Assessment
Sergii Skakun, **Ukraine/Poland**	**U. Maryland**		High-Impact Hot Spots of Land Cover Land Use Change: Ukraine and Neighboring Countries
Nicholas Magliocca **Central America** **New PI to LCLUC**	**U. Alabama**		Making the Hidden Visible: Accelerated Land-Use Change and Degradation Caused by Narco-Trafficking In and Around Central America's Protected Areas

Conclusions

MuSLI provides PI's the support needed to ***harness a richer set of Earth Observations*** to better characterize land and coastal processes

As combined use of Landsat and Copernicus data has become commonplace, MuSLI program has evolved to focus on new "tall poles" of multi-sensor fusion

- Integration of VHR commercial imagery
- Application of multi-modal data (SAR, multispectral, hyperspectral, lidar)
- Robust & validated application of ML and AI