25 YEARS OF EXTERNAL INTERACTIONS: NATIONAL

- **U.S. Global Climate Research Program (USGCRP)**
  - LULCC Interagency Working Group
  - Our Changing Planet issues
  - NAS NRC review of land-use models

- **U.S. Geological Survey (USGS)**
  - Landsat program
  - USGS science projects’ support
  - Global Land Surveys (Landsat-based)

- **Private sector: Planet Lab, Maxar**
  - NASA Commercial Smallsat Data Acquisition (CSDA)

- **Academia**
  - Research projects’ support

- **U.S. Department of Agriculture (USDA) and U.S. Forest Service (USFS)**
EXTERNAL LINKAGES: INTERNATIONAL

- Global Observations of Forest Cover and Land-use Dynamics (GOFC-GOLD) since 1997
- CEOS/GEO
- IGBP/IHDP → Future Earth
  - Global Land Program (GLP)
- EARSeL (EU Remote Sensing Labs)
  - LULC Special Interest Group
- Regional Initiatives
  - SAFARI (South Africa)
  - LBA (Amazon)
  - NEESPI (Northern Eurasia)
  - MAIRS (Monsoon Asia)
  - SARI (South/Southeast Asia)
- Space agencies (ESA, JAXA, etc.)
25-yr Program stats:
- >300 projects
- ~50 ongoing
- >800 researchers
- >20 post-docs
- >50 grads
- >1000 publications
UNIQUENESS OF THE LCLUC GLOBAL SCIENCE PROGRAM

- **Socio-economic component:** an integral part of the projects
  - impacts of changes in human behavior and economy on LCLUC
  - impacts of LCLUC on society
  - adaption to climate change of land-use systems
  - a mandatory part of all LCLUC proposals, except MuSLI

- **Remote sensing component:** Multi-Source Land Imaging (MuSLI) component with medium or higher resolution

- **Regional Initiatives:** focus on Hotspots

- **Capacity Building/Education component**
LCLUC Science Team Meetings in DC Area

2007: Climate/Carbon
2008: Joint CC&E Focus Area/Arctic
2009: LCLUC impacts on climate
2010: GLS LCLUC products
2011: 15th Anniversary (review)
2011/9: Joint CC&E Focus Area/Ag
2012: Urban
2013: Wetlands
2014: Urban

Spring Blossom <-> Fall Colors

2016: 20th Anniversary/Industr. Forests
2015: Joint CC&E FA/LCLUC Modeling
2017: Mountains & MuSLI
2018: SARI-1: South Asia/MuSLI
2019: SARI-2: SE Asia/Caucasus
2020: MuSLI (virtual)
2022: 25th (Silver) Anniversary/AFOLU
2023: Joint CC&E FA/Hot spots
International Regional Science Team Meetings

2007/9: NEESPI/MAIRS
Urumqi, China

2009/1: MAIRS
Kohn Kaen, Thailand

2009/9: MAIRS/NEESPI
Almaty, Kazakhstan

2010/8: NEESPI
Tartu, Estonia

2011/11: MAIRS
Hanoi, Vietnam

2012/3: SARI
Yangon, Burma/Myanmar

2014/10: NEESPI
Sopron, Hungary

2016/1: SARI
Chiang Mai, Thailand

2017/7: SARI
Chiang Mai, Thailand

2018/05: Laze
Philippines

2019/7: NEESPI
Johor Bahru, Malaysia

2020/2021 skipped

2022/8: Phnom Penh,
Cambodia

2023/8: Fortaleza,
Brazil
NASA Operating Missions

Over 50 Years in Space!

Earth Fleet

Invest/Cubesats
- TEMPEST-D 2021
- CSIM-FD 2023
- HARP 2020
- CIRIS 2022
- CTIM* 2023
- HYI* 2021
- SNOOPI* 2023
- NACHOS* 2023

JPSS Instruments
- OMPS-LIMB 2022
- LIBERA 2027

ISS Instruments

Missions

Landsat next

Key
- International Partner
- U.S. Partner
- ISS Instrument
- JPSS Instrument
- Cubesat
- Launch Date TBD

- Preformulation
- Formulation
- Operating
- Extended
NASA LCLUC-Relevant Missions

**Systematic Missions** - Observation of Key Earth System Interactions

- **Landsat 5 & 7** 3/1/84 & 4/15/99
- **Terra** 12/18/99
- **Aqua** 5/3/02
- **Suomi-NPP** 10/28/11
- **Landsat 8** 2/11/13
- **Landsat 9** 9/27/21

**Exploratory Missions** - Exploration of Specific Earth System Processes and Demonstration of Technologies

- **ShuttleRadar Topography Mission (SRTM)** 2/11/02-2/22/02
- **Earth Observing EO-1 (AOI)**
  - Hyperion – first hyperspectral in space 11/21/00-3/30/2017
- **International Space Station (ISS)**
- **ECOSTRESS** (thermal IR) Deployed in 2018
- **GEDI** (Lidar)
- **DESIS** (Hyperspectral)
The Landsat program: Earth Resources Technology Satellites Program 1966, Landsat 1 (ERTS) launched in July 1972
Thermal band added for Landsat 3 and beyond
After launch, Landsat operations are transferred from NASA to USGS to collect, archive, process, and distribute the image data
Until 2010 expensive, FREE NOW!
Two-Landsat system frequency revisit time: 8 days -- in some areas may not provide enough observations for monitoring rapid changes (e.g., Ag) but sufficient for slow changes (e.g., Urban)
April marked the 15-year anniversary of the USGS announcement to ‘open’ the Landsat archive at the USGS Earth Resources Observation and Science (EROS) Center, making all Landsat data available to download at no charge for users worldwide.

Barb Ryan, former Associate Director of Geography for USGS, and (more recently) former Secretariat-Director for the Group on Earth Observations (GEO)
Merging Sentinel-2 and Landsat data streams could provide < 5-day coverage required for Ag monitoring

- Both sensors have 10-30m coverage in VNIR-SWIR
- Satellite orbits complementary
  - Landsat-8 & -9  8 days
  - Sentinel-2a & 2b 5 days
- Global ~3 day
- Merging in Sentinel-1 radar data provides all-weather microwave observations

COMBINING OPTICAL AND MICROWAVE DATA:
LANDSAT + SENTINEL2 + SENTINEL1

**MuSLI Solicitations:** LCLUC-2014 (merging Landsat and Sentinel-2); LCLUC-2017 (incl. Radar data); LCLUC-2020 (incl. VHR data); LCLUC-2023 (incl. IR data and all of the above)
NEW OPPORTUNITIES

SENSORS ON ISS FOR LCLUC STUDIES

• **ECOSTRESS**: ECOsystem Spaceborne Thermal Radiometer Experiment on ISS
  - Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR)
  - 5 spectral bands in the 8-12.5 μm range + 1.6 μm (69m x 38m)

• **DEISIS**: DLR Earth Sensing Imaging Spectrometer
  - 235 spectral channels with ground res. 30m

• **GEDI**: Global Ecosystem Dynamics Investigation
  - high resolution laser ranging observations of the 3D structure of the Earth
  - three lasers produce eight parallel tracks of observations
  - each laser fires 242 times per second and illuminates a 25 m spot (a footprint) on the surface over which 3D structure is measured

RECENT AND UPCOMING MISSIONS

• **SWAT**: Surface Water and Ocean Topography
• **NISAR**: NASA-ISRO SAR
ECOSTRESS: NASA INSTRUMENT ON ISS

ECOSYSTEM SPACEBORNE THERMAL RADIOMETER EXPERIMENT ON THE INTERNATIONAL SPACE STATION (ISS)

- **Prototype HyspIRI Thermal Infrared Radiometer**
  - 5 spectral bands in the 8-12.5 \(\mu\)m range +1.6 \(\mu\)m
  - Spatial resolution ~70 m
  - Advantage over ASTER (on TERRA) – more frequent revisit

- **Science objectives**
  - Identify critical thresholds of water use and water stress in key biomes (e.g., tropical/dry transition forests, boreal forests)
  - Detect the timing, location, and predictive factors leading to plant water uptake decline and cessation over the diurnal cycle
  - Measure agricultural water consumptive use over CONUS at spatiotemporal scales applicable to improving drought estimation accuracy

Credit: NASA/JPL-Caltech

Heatwave over Europe: June 2019
**DLR EARTH SENSING IMAGING SPECTROMETER (DESIS) ON ISS**

- Launched to the International Space Station (ISS) from Cape Canaveral on **29 June 2018**
- Deployed in **Aug 2018** to observe the Earth and provide **hyperspectral data** to support scientific,
- DESIS has **235 spectral channels** with ground resolution 30m
- Can point forwards, backwards and to the sides

[First images of the hyperspectral instrument DESIS. Left: Optical image of the environment of Huntsville, AL; Right: A processed image showing the vegetation density (image credit: DLR)](https://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10212/332_read-28665/#/gallery/30169)
High resolution laser ranging observations
- three lasers produce eight parallel tracks of observations
- each laser fires 242 times per second and illuminates a 25 m spot (a footprint) on the surface

Integration of the GEDI lidar forest structure measurements and Landsat analysis-ready data time-series Potapov et al. 2020, RSE
NASA-CNES SURFACE WATER AND OCEAN TOPOGRAPHY (SWOT)

- SWOT's 120-km-wide swath with overlaps over most of the globe with an average revisit time of 11 days
- Launched Dec 16, 2022
- On land, it will collect data on lakes and reservoirs larger than 62,500 m² and rivers wider 100 m with 50-m spatial and 10-cm height resolutions
- All weather - penetrate cloud cover and the dark of night

SWOT will survey nearly all water on Earth’s surface for the first time with Ka-band Radar Interferometer (KaRIn, frequency between 26.5 and 40 GHz)
NASA-ISRO SAR (NISAR)

- Will observe Earth’s land and ice-covered surfaces globally with 12-day repeat cycle
- Swath of 242 km
- Resolution 3–48 m for L-band
- Resolution of 3-24 m for S-band
- Planned Launch Date: 2024
- Will observe the distribution of vegetation and biomass to better understand ecosystems’ responses to disturbance and recovery
- Will map above-ground woody biomass density for estimating carbon emissions from land-use change with much more accuracy

L-band (24 cm) and S-band (12 cm) polarimetric SAR
MORE DISTANT FUTURE: LANDSAT NEXT

• Constellation of 3 small satellites
• 26 wavelengths bands
• More frequent and finer resolution
• Launch: late 2030

Landsat Next constellation of three spacecraft will provide finer spatial resolution (10–20m) and expanded spectral (26 band) imaging capabilities every six days (at the equator).
ZOOMING-IN:
USING VERY HIGH RESOLUTION DATA

Commercial satellites offer images at fine spatial scale and high temporal resolution

- The first NASA Data Buy 2003 – Ikonos
- **Planet Labs** constellation (>200 sats) acquire daily images of the Earth with 3-m resolution
- **Maxar (Digital Globe, WorldView)** with 1m resolution

- **NASA Commercial Smallsat Data Acquisition (CSDA)**
  - Limited Planet datasets are available for free at Universities
  - Wall-to-wall VHR data over tropics purchased by the government of Norway (to tackle tropical deforestation)
  - Special Issue in Remote Sensing (2020) on applications of VHR data in LCLUC studies
REJUVENATION OF LCLUC: LCLUC-19 SELECTEES

Nick Cuba, Auburn U.
MEHA JAIN, U. MICHIGAN
Zhenong Jin, U. Minnesota
Carlos Munoz Brenes, Conserv. Int.

Xiaopeng Song, Texas Tech U, U. Maryland
Robert Heilmayr, UC Santa Barbara
Xin Xi, MICHIGAN TECH. U
Aaron Sparks, U. Idaho
Chris Nolte Boston U.
REJUVENATION OF LCLUC: LCLUC-21 SELECTEES

Qiongyu Huang, Smithsonian Inst.

McKenzie Johnson, U. Illinois

Nimrod Carmon, JPL

Sean Woznicki, Grand Valley State U.

Eleanor Stokes, Universities Space Research Association

Alexey Shiklomanov, NASA GSFC

Nina Brooks, U. Connecticut

Latha Baskaran, JPL
National Distribution of PI Institutions

LCLUC-20

- Jody Vogeler
  Colorado State University
- Volker Radeloff
  University of Wisconsin, Madison
- David Skole and David Roy
  Michigan State University
- Christopher Neigh
  NASA GSFC
- Yufang Jin
  UC Davis, California
- Sean Healey
  Rocky Mt. Research Station
  US Forest Service, Utah
- Nicholas Magliocca
  U. of Alabama, Tuscaloosa
- Marc Simard and Mike Keller
  JPL
- Sergii Shakun and Alexandra Tyukavina
  U. of Maryland College Park

LCLUC-21

- Sean Woznicki
  Grand Valley State University, MI
- Alexey Shkilmanov
  NASA GSFC
- Eleanor Stokes
  Earth from Space Inst.USRA
- Nina Brooks
  Univ. of Connecticut
- Nimrod Carmon and Latha Bhaskaran
  JPL
- McKenzie Johnson
  University of Illinois Urbana-Champaign
- Qiongyu Huang
  Smithsonian Institution

LCLUC-22

- Jamon Van Den Hoek
  Oregon State University
- Cascade Tuholske
  Montana State University
- Geoff Henebry, Lin Yan
  Michigan State University
- Gillian Galford
  University of Vermont
- Robert Pontius
  Clark University
- Xiapeng Song
  University of Maryland College Park
- Elsa Ordway
  University of California, Los Angeles
- Saurav Kumar
  Texas A&M University
- Elizabeth Hunter
  Virginia Tech
- Grant Connette
  Smithsonian Institute
Distribution of Study Regions

LCLUC-20

LCLUC-21

LCLUC-22
HOTSPOTS OF LAND USE
GLOBAL MAP OF HOTSPOTS OF LAND COVER AND LAND USE CHANGE

Purpose: The goal of this project is to present examples of current hot spots of land cover and land use change around the globe, through an interactive online map. This project was a collaboration between graduate students in the Department of Geography at the University of Maryland, College Park, and was completed in late 2009. The site is periodically updated as new hotspots are identified by scientists from NASA’s Land-Use Land-Cover Change Program.

Hotspot Definition: For the purposes of this project, a “hotspot” is defined as existing or potential change to a region or area through land cover and land use change that has regional to global implications. The hotspots were also considered within the context of pressing environmental and social issues such as climate change, biodiversity, human health, and sustainability. Primary considerations were to identify areas of change within the last five years and areas of continued or potential future change.

Hotspot Categories: Seven broad categories of land-cover land-use change were identified for this project. In some cases the categories are related to one another, and other hotspots can be added as needed.
Forests are the lungs of the planet, capturing vast amounts of carbon dioxide, releasing oxygen, and protecting soil, fresh water, and up to 90 percent of all terrestrial species in the bargain. Yet humans continue to mow down forests as if they were lawns. Half the forests that stood 8,000 years ago have been destroyed—much of them during the past 400 years—while only a fifth remain in large undisturbed tracts. Each year the world cuts an area larger than Florida, with the greatest rates of deforestation occurring in South America, Africa, and Southeast Asia. Forests are such massive reservoirs of carbon that their loss in the tropics alone released about a fifth of all human-caused carbon dioxide emissions in the past decade.
Pre-NEESPI Product: Intact Forest Landscapes of Northern Eurasia:
NASA + World Resource Institute + Green Peace Russia

Peter V. Potapov, UMD
Svetlana Turubanov, UMD
DATA ASPECTS

- NASA LCLUC program expects its PIs to make their data and products available to the community for free and open access
- LCLUC metadata page
- Very High-Resolution (VHR) data for NASA-affiliated scientists

LCLUC PIs must provide metadata on data products generated under NASA-funded projects

<table>
<thead>
<tr>
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<th>Team</th>
<th>Institution</th>
<th>Project Start Date</th>
<th>Project End Date</th>
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<tbody>
<tr>
<td>Land Use Status, Change and Impacts in Vietnam/Cambodia/Laos</td>
<td>Land Use Status, Change and Impacts in Vietnam, Cambodia and Laos</td>
<td>Jon Nelson, Andrea Gassman, Forrest Stevens</td>
<td>Jet Propulsion Laboratory</td>
<td>05/01/2018</td>
<td>12/31/2021</td>
</tr>
<tr>
<td>Understanding the Role of Land Cover/Land Use Nexus in Malaria Transmission Under Changing Socio-Economic Climate in Myanmar</td>
<td>Understanding the Role of Land Cover/Land Use Nexus in Malaria Transmission Under Changing Socio-Economic Climate in Myanmar</td>
<td>Tatiana Loboda, Mark Carroll, Julie Silva, Myung Nyunt, Christopher Plowe, Kathleen Stewart</td>
<td>University of Maryland</td>
<td>05/01/2017</td>
<td>03/01/2020</td>
</tr>
</tbody>
</table>

Commercial Smallsat Data Acquisition (CSDA) Program Update

The commercial data currently distributed by NASA are available under different scientific use licenses and various access portals. The Commercial Smallsat Data Acquisition (CSDA) program evaluates and procures data from commercial vendors that advance NASA’s Earth science research and applications activities. Currently, data acquired during the evaluations of Planet, Maxar (formerly DigitalGlobe, Inc.), and Spire Global are available. Data from the Teledyne Brown Engineering, Inc., DLR Earth Sensing Imaging Spectrometer (DESIS) also are available through a separate collaboration with the International Space Station (ISS).

More Info: https://earthdata.nasa.gov/esds/csdap/commercial-datasets

PDF file: CSDA_ROSES_data_access_overview[1].pdf

OPEN SCIENCE @NASA WILL BE COVERED IN THE LAST SESSION (THE WRAPUP)
LCLUC 2023-MUSLI

• Proposals on the enhanced use of MuSLI methods, which would combine **infrared data (from SWIR to TIR)** with optical and/or microwave data, to study LCLUC

• Does NOT require the incorporation of a socio-economic research it but may be included

• Two-step procedure

  Step-1: 48 submitted
  26 encouraged

  05/23/2023
  Step-2 due date

• Anticipated 10 selections for 2.5M/year for three years
A High Spatio-Temporal Resolution Land Surface Temperature (LST) Product for Urban Environments

Water Use in Agricultural and Modeling

Coordination, Calibration and Algorithm Development of the Thermal Infrared Activities for the ESA Land Surface Temperature Monitoring (LSTM) Mission and NASA Surface Biology and Geology (SBG) Designated Observable

* ECOSTRESS was not decommissioned in 2022 !!
* The 2nd most requested product in the LP DAAC AppEEARS data access tool (among 120+ products)
A novel NASA-funded infrared radiometer

**Third year in Earth orbit** - a new milestone for a small satellite that may make a huge impact on infrared imaging

Developed by Ball Aerospace with support from NASA’s ESTO

Technology validation mission gathering infrared images of Earth’s surface

**New uncooled bolometer** and associated calibration system **without a cryogenic cooler**, reducing the weight, complexity, and cost

  * Three calibration views: one that looks towards space and two that look towards flat-panels coated with vertically aligned carbon nanotubes (an extremely black substance)

CIRiS isn’t the first space-based infrared imager, but it is **one of the smallest**. (weighing less than four pounds)
MORE DISTANT FUTURE:
ESTO ROSES-2019 SELECTED PROPOSALS ON IR SENSORS
(SEE ESTO WEBSITE FOR DETAILS)

- **Super Uncooled Multi-Band Radiometer Sensor (SUMRS)**
  - DRS Network & Imaging Systems, LLC
  - In response to the Sustained Landsat Imaging Technology ESTO call in 2020
  - For potential infusion into the architecture and design of missions
  - Will provide temporal/spatial simultaneous imaging in 6 spectral bands at 30m with a sensitivity better than the current LANDSAT 8/9 TIRS
  - [https://esto.nasa.gov/project-selections-for-sli-t-19/](https://esto.nasa.gov/project-selections-for-sli-t-19/)

- **Versatile Computational Pixel Infrared Land Imager**
  - Jet Propulsion Lab
  - Spectral coverage from the near infrared to the very long wavelength infrared

- **Reduced Envelope Multispectral Infrared Radiometer (REMIR)**
  - Ball Aerospace & Technologies Corporation
  - Single, full spectral range (VIS-TIR)
  - Robust airborne demonstration platform to verify the ability of uncooled microbolometer CIRiS calibration system approach

Looking into the future: beyond Landsat-Next (10)
EDUCATION AND OUTREACH

- E-Newsletters
- Webinars
Curator: Melanie R.

- LCLUC website
- Facebook page

The Program needs
- One-pagers showcasing the project
- Statistics on grad. students
- Publications
- Media
- Project info for the Mapper

Meghavi is the POC for all the info (cc Chris, Krishna and me)
A GLIMPSE INTO LCLUC HISTORY: THE BROCHURES

BEFORE WE STARTED E-NEWSLETTERS

The first LCLUC brochure designed and compiled by Inbal Reshef

Each of them are on exhibit (not for distribution) – for younger researchers to look into LCLUC history

2006

Design: Catherine Nakalembe

2009

Design: Lydia Prentiss

2012
>200 articles in these special issues involving more than 100-institutions from the US, South/Southeast Asia and worldwide
SPECIAL ISSUE "FRONTIERS IN REMOTE SENSING" (SEP 2022)
OUR CHANGING PLANET: HALF-A-CENTURY LANDSCAPE DYNAMICS OBSERVED FROM SPACE
EDITORS: G. GUTMAN, C. JUSTICE, E. VERMOTE

Last 12 months

60,927 total views | 54,045 views | 4,450 downloads | 2,432 topic views

63,985 total views
4,947 downloads
2,432 topic views

United States of America 1,194
India 107
Germany 81
United Kingdom of Great Britain and Northern Ireland 73
Russian Federation 34

7 Articles
The 2 most viewed articles:

- Global Trends of Forest Loss Due to Fire From 2001 to 2019. Tyukavina et al. (31,795)
- The Global 2000-2020 Land Cover and Land Use Change Dataset Derived From the Landsat Archive: First Results. Potapov et al. (21,279)
LCLUCERS IN MEDIA AND AWARDS: 2022-2023

**Exceptional Public Achievement Medal**
- BBC world news interviewed Dr. Inbal Becker Reshef on how satellite information can be used to improve food security and agricultural decisions. Feb 2022

**Exceptional Service Medal**
- Chris Justice, interviewed by AGU Third pod from the Sun – AGU’s podcast. Jan 2023

**Kuno Award for Applied Sciences**
- Eleanor Styokes, contributed to the story on the recent earthquake in Turkey and Syria (tracking electrical infrastructure damage) highlighted in the Washington Post, 2023

**NASA Earth Observer** referred to Sergii Skakun’s work on crop monitoring in Ukraine under war situation. Dec 2022

**The New York Times** referred to Jeff Fox’ work in a story on how Nepal grew back its forests. Nov 2022
- Radio Free Asia referred to Jeff Fox’s work on crops with a story that Southeast Asia remains world rice bowl as pockets of region suffer crop disasters. Nov 2022

*Much of the tree growth in the tropics in the first decade of the century consists of plantations — not natural forest* - LCLUC project’s findings by PI Nick Magliocca, Co-I Mathew Fagan and team were featured in *Nature*’s Research Highlights. Oct 2022
THANKS GO TO

- Organizers: C. J. and Co.
- Mary, Meghavi, Jack, Melanie, Rohan
- Our major, loyal sponsor
Enjoy Spring Blossoms