

Summary of the 2020 NASA Land-Cover and Land-Use Change Annual Science Team Meeting

Meghavi Prashmani, University of Maryland, College Park, meghavi@umd.edu

Krishna Vadrevu, NASA's Marshall Space Flight Center, krishna.p.vadrevu@nasa.gov

Chris Justice, University of Maryland, College Park, cjustice@umd.edu

Garik Gutman, NASA Headquarters, garik.gutman@nasa.gov

Introduction

The 2020 NASA Land-Cover and Land-Use Change (LCLUC) Science Team Meeting (STM) was held virtually from October 19-21, 2020. A total of 357 participants were invited from 32 countries, out of which 258 attended the meeting from across the world. **Photo 1** is a group photo of many of the participants.

The following summary is organized approximately chronologically by day. The meeting presentations can be accessed from <https://lcluc.umd.edu/meetings/2020-nasa-lcluc-annual-science-team-meeting?page=>.

DAY ONE

Day one comprised an LCLUC program overview, two (of three) invited presentations from NASA Headquarters (HQ), and updates on the Multi-Source Land Imaging (MuSLI) program.

Chris Justice [University of Maryland, College Park (UMD)—*LCLUC Project Scientist*] was the moderator for the first day. **Photo 2** on page 23 shows speakers from NASA HQ and LCLUC Program Leads.

Welcome and LCLUC Program Overview

The meeting began with welcoming remarks from **Garik Gutman** [NASA HQ—*LCLUC Program Manager*], who shared the latest summary of program developments and achievements. This year's STM was dedicated to Anthony “Tony” Janetos, the founding Program Manager of the LCLUC program, who passed away on August 6, 2019.

Chris Justice reflected on Janetos's accomplishments and highlighted his contribution to the LCLUC program. LCLUC researchers paid tribute to Janetos by sharing their memories of the first few years of the Program—see *In Memoriam: Anthony “Tony” Janetos* on page 22.



Photo 1. Group photo of many (not all) virtual participants of the 2020 LCLUC Science Team Meeting. **Photo credit:** Meghavi Prashmani

In Memoriam: Anthony “Tony” Janetos (1954-2019)

The 2020 LCLUC STM was dedicated to its founding program manager, Anthony “Tony” Janetos who passed away on August 6, 2019.



The NASA LCLUC program is saddened to report the passing of founding Program Manager, Anthony “Tony” Janetos, who was an international leader in climate change science, science policy, and global environmental assessments. He received his Ph.D. in Biology (1980) from Princeton. In 1990 he joined NASA as the Manager of the Terrestrial Ecology Program. He was NASA’s representative to the U.S. Global Change Research Program (USGCRP) and the working group of the Committee on Environment and Natural Resources (CENR). In 1993, he became Chief of the Ecology and Atmospheric Chemistry Branch and Program Scientist for Landsat and the Earth Observing System (EOS) AM-1 (Terra) Platform. In 1994 he was Chief of the Earth System Models and Ecological Processes program, and in 1996 and 1997, he received Director’s Award from the Science Division Mission to Planet Earth. He also advised the United Nations on climate change and co-authored a number of Intergovernmental Panel on Climate Change (IPCC) reports. Tony became LCLUC Program Manager in 1995, inviting Chris Justice to be Project Scientist to support the program. Tony had a strong vision for the LCLUC program, and he recognized that land use science is interdisciplinary and policy-relevant, plus that the socio-economic dimension is integral to understanding land use.

“Tony was a wonderful colleague and a pleasure to be with. He was direct, open, and clear-minded, and a quick learner. He had a good grounding in ecology with a strong vision for Earth science, climate change, and sustainability.” —Chris Justice

Tony left NASA in 1999 to join the World Resource Institute as Senior Vice President and Chief of the Program. From 2003 to 2006, he served at the Heinz Center for Science, Economics, and the Environment, and in 2006 he was Director of the Joint Global Change Research Institute at the University of Maryland, College Park, where he supervised an interdisciplinary team of natural scientists, engineers, and social scientists committed to understanding the problems of global climate change and their potential solutions.

“Tony was a special person. Decades ago he pursued his vision for the Land Use Land Cover Change program and made it a reality. The entire community owes him a great deal of gratitude. We will miss his calm and steady presence.” —Ruth DeFries

Tony was an influential leader in the global change community and contributed to the U.S. Climate Change Science Program (US CCSP), serving as co-chair of the National Assessment Synthesis Team, a body charged with providing intellectual leadership and oversight of the U.S. National Assessments of the Potential Consequences of Climate Variability and Change. He served as a Coordinating Lead Author in the Ecosystems Trends and Conditions component of the Millennium Ecosystem Assessment and contributed to the UNEP Global Biodiversity Assessment.

“Tony made significant contributions to science. He headed many advisory committees; he had a great impact on many NASA and NSF [National Science Foundation] programs and across a number of federal agencies. He was a great fun fellow to be around.” —David Skole

Tony was instrumental in the initial development of the international GOF-C-GOLD* program and served as Chair of the Steering Committee (2007-2010) and Program Chair (2010-2019). He was a member of the Scientific Steering Committee for the International Geosphere-Biosphere Programme (IGBP) Global Land Project (2009-2012). In 2013, he joined Boston University as the Director of the Frederick S. Pardee Center for the Study of the Longer-Range Future and as a Chair and Professor of the Earth and Environment Department. In 2017, he participated in NASA’s Decadal Survey.

“Tony was a great colleague and mentor to many of us and we have much to thank him for. The LCLUC community will miss his scientific insight, his congeniality, and positive outlook.” —Garik Gutman

*GOF-C-GOLD stands for Global Observations for Forest Cover and Land-Use Dynamics.



Photo 2. Invited speakers from NASA HQ [top, left to right] Karen St. Germain, Sandra Cauffman, and Jack Kaye and NASA LCLUC Program Leads [bottom, left to right] Garik Gutman, Chris Justice, and Krishna Vadrevu. Photo credit: Meghavi Prashnani

Invited NASA HQ Presentations

Following these welcoming remarks, there were two presentations from representatives of NASA HQ to place the LCLUC Program within the larger context of NASA's Earth Science Division (ESD). **Karen St. Germain** [NASA HQ—*Director of the ESD*], who became Director in June 2020, shared her perspective and near-term priorities of the ESD for the coming decade. She acknowledged that the ESD has holistic end-to-end programs focusing on research, development, and observations useful for decision-making. She emphasized the importance of making actionable information available to decision makers at all levels: federal, local, tribal, emergency responders, and non-government organizations.

Following on St. Germain's comments, **Jack Kaye** [NASA HQ—*Associate Director for Research of the ESD*] emphasized that interdisciplinary science and international engagement are critical components of the ESD. He noted that for a long time, the LCLUC Program has contributed substantially to achieving this goal by integrating natural and social sciences in its projects and collaborating with regional scientists worldwide.

Multi-Source Land Imaging Program Overview

The MuSLI program provides support to researchers to utilize multiple sources of Earth observations for a better characterization of land-use and coastal processes. **Jeff Masek** [NASA's Goddard Space Flight Center (GSFC)—*MuSLI Project Scientist*] explained the evolution of the MuSLI program over the past six years since its inception and how it serves as a bridge between the supply and demand side of the satellite data. On the supply side, a number of satellite datasets are available since 1972, but in the last decade the availability of remote sensing data exploded, especially due to the European Space Agency's Sentinels¹ and other national and international missions, e.g., VENμS (Israel

and France),² Resourcesat (India),³ and RADARSAT (Canada).⁴ Also, commercial very high-resolution satellite data from private companies (e.g., Maxar Technologies⁵ and Planet⁶) have become more readily available. On the demand side, the land science and application user communities have a need for dense time series of imagery to quantify the rapid LCLUC including vegetation phenology, surface hydrology, and land management practices. Integration of the multi-source satellite data is a complex process that entails integration of multiple datasets with different formats while simultaneously maintaining the spatial and temporal consistency including calibration, and developing products to meet user needs. Masek concluded his presentation illustrating one of the MuSLI products; he showed the continental-scale land surface phenology from the Harmonized Landsat Sentinel (HLS) database (combining data from Landsat 8 and Sentinel-2)—see **Figure 1** on page 24.

Following Masek's address, eight MuSLI scientists presented their project updates, starting with updates from three MuSLI Type-1 projects aimed at building continental-scale products. Algorithms for these projects were prototyped in the first stage of the MuSLI round and are currently being implemented on a continental scale in their second stage. Following this were presentations on five Type-2 MuSLI projects, which are presently building regional-scale prototypes

² VENμS is the first cooperative Earth observation program of Israel (ISA) and France (CNES). The minisatellite mission is being developed jointly by the Israeli Space Agency (ISA) and the French Centre National d'Études Spatiales (CNES), under a memorandum of understanding between the two space agencies.

³ The Resourcesat satellites are built by the Indian Space Research Organisation (ISRO), which continues the remote sensing data services provided by the Indian Remote Sensing Series (IRS)-1C and -1D.

⁴ RADARSAT is a Canadian remote sensing Earth observation satellite program overseen by the Canadian Space Agency (CSA).

⁵ Maxar Technologies is a space technology company headquartered in Westminster, CO, specializing in manufacturing communication, Earth observation, radar, and on-orbit servicing satellites, satellite products, and related services.

⁶ Planet is an Earth-observing remote sensing company in San Francisco, CA. It currently operates two smallsat constellations (DOVE and RapidEye).

¹ The European Space Agency has developed the Sentinels to meet the operational needs of its Copernicus programme. To learn more, visit https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Overview3.

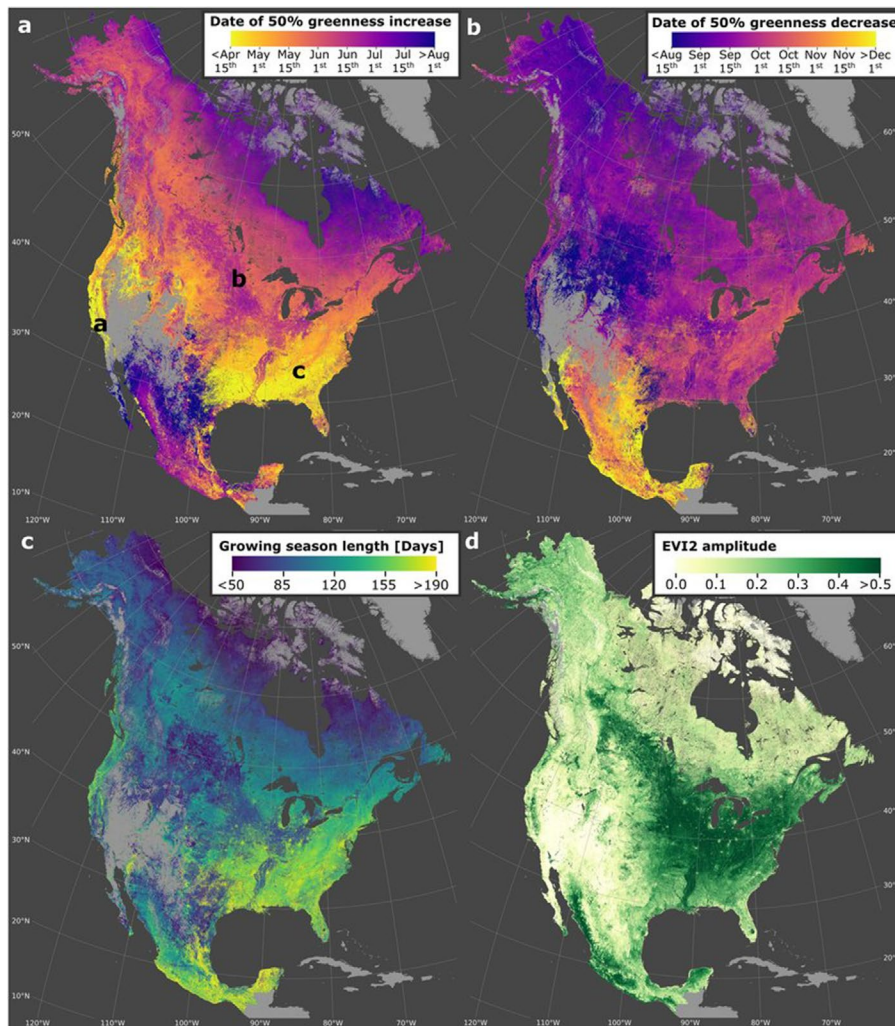


Figure 1. Continental patterns in the timing of spring green-up [*top left*] and fall green-down [*top right*] show strong geographic variation related to climate forcing and land use. Continental-scale patterns in growing season length [*bottom left*] and two-band Enhanced Vegetation Index (EVI2) amplitude [*bottom right*] reflect similar geographic patterns. **Image credit:** Mark Friedl [Boston University]

where algorithms are still being developed. All eight talks covered a variety of MuSLI applications, including imaging of seasonal dynamics of land surface, circumpolar albedo, burned area estimation, urban heat islands, and crop yield assessments. **Garik Gutman** summed up the day discussing the accomplishments and future direction for the MuSLI program.

DAY TWO

The second day focused on the South/Southeast Asia Research Initiative (SARI) with several presentations that provided updates on various aspects of the initiative and a panel discussion on the SARI synthesis.

Krishna Vadrevu [NASA's Marshall Space Flight Center (MSFC)—*LCLUC Deputy Program Manager, SARI Project Scientist*] chaired the second day's activities.

Update on SARI Activities

Krishna Vadrevu kicked off the second day, providing an update on SARI for the LCLUC ST. He presented various activities and studies carried out under SARI since its inception, including regional meetings, capacity building training, publications, collaborations, solicitations, and field visits. Over the past five years,

22 different projects were funded by the LCLUC program under the SARI umbrella. Of these, 12 are in South Asia and 10 in Southeast Asia. These 22 projects involved more than 250 U.S. and international scientists from over 150 organizations. To date, nearly 250 papers have been published in peer-reviewed journals and 12 different special issues have been produced through SARI collaborations. The SARI program organized several regional meetings in countries such as Vietnam, Thailand, Indonesia, Burma, and India,⁷ involving space agencies, governmental and non-governmental organizations, local universities, students, and professionals from related sectors. These regional meetings have helped U.S. scientists develop international collaborations in different countries, useful for validation of several NASA satellite datasets, testing novel algorithms, and sharing science results and information with local decision-makers. The SARI program is involved in organizing multiple capacity building and training events in developing countries to train young researchers on novel

⁷ For a recent example, see “Summary of the 2019 SARI Sustainable Forestry in South Asia Meeting” in the September–October 2020 issue of *The Earth Observer* [Volume 32, Issue 5, pp. 21–26—<https://go.nasa.gov/3jz0j6f>].

remote sensing and geospatial technology and tools useful for research and applications.

Presentations on LCLUC Issues in South and Southeast Asia

After the programmatic overview of SARI, the focus turned to summaries of the individual SARI projects. As with the programmatic presentations, the reports on individual SARI projects highlighted specific LCLUC issues in South and Southeast Asia. Over the last several decades, this area of the world has experienced extremely rapid land-use and land-cover changes. Two SARI Principal Investigators (PIs) gave overview presentations on SARI activities in Southeast and South Asia respectively, which are summarized in what follows.

Overview Presentations

Jefferson Fox [East-West Center, Hawaii] presented an overview of identifying trends and ongoing issues in Southeast Asia—see **Figure 2**. There has been a rapid expansion of large-scale agro-businesses in the region, especially rubber and oil palm, expanding to other tree crops, orchards, coffee, and fast-growing trees (for pulp

and paper)—all of which SARI PIs have investigated. For future projects, Fox suggested the LCLUC program address other drivers of LCLUC besides rice, palm, and rubber. He also suggested having more projects covering the entire Southeast Asia region to capture a wider range of LCLUC issues.

Ruth DeFries [Columbia University] presented an overview of LCLUC projects in the South Asia region—see **Figure 3**—stressing that the region possesses very distinctive characteristics compared to the rest of the world, making the LCLUC studies important for the sustainable development of the region. This region is experiencing water stress, crop stress, a strain on the energy system, rapid LCLUC, massive agricultural expansion and intensification, with high-density and increasing population. However, on a positive note, South Asia has a lot of degraded lands that could potentially be put to good use for the benefit of people’s livelihoods, environmental restoration, and climate mitigation. DeFries explained that South Asia presents a challenge for land-cover/use assessment because there are large areas with sparse vegetation, scattered forests, trees outside forests, fragmented

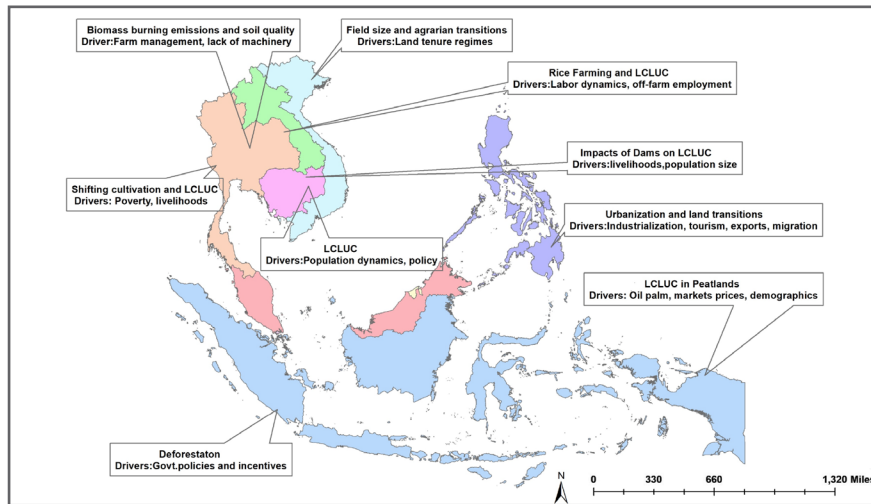


Figure 2. LCLUC drivers in Southeast Asia as identified by LCLUC SARI project PIs and covered in Jefferson Fox’s overview presentation. **Image credit:** Krishna Vadrevu

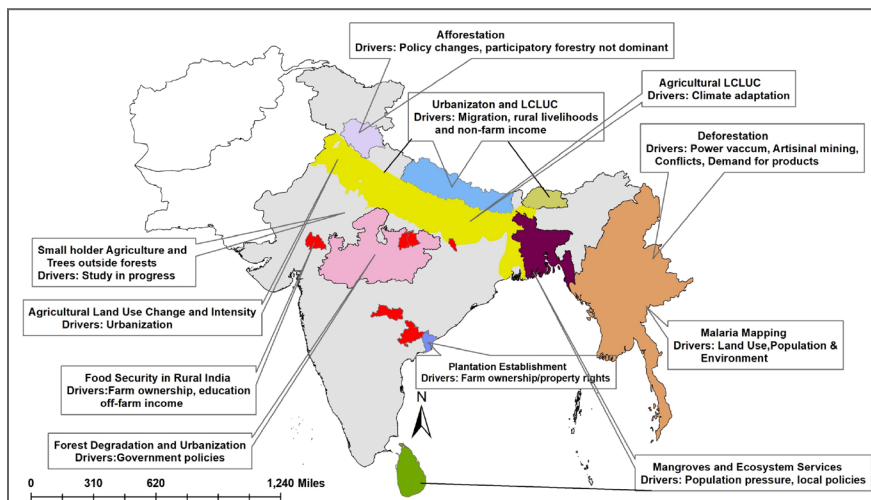


Figure 3. LCLUC drivers in South Asia as identified by LCLUC SARI project PIs and covered in Ruth DeFries’ overview presentation. **Image credit:** Krishna Vadrevu



Photo 3. Space Agency Leads from South/Southeast Asia. [Top row, left to right] **Prakash Chauhan** [ISRO], **Shinichi Sobue** [JAXA], **Lam Dao Nguyen** [VNSC] and [bottom row] **Tatia Chuentragun** [GISTDA], **Rokhis Khomruddin** [LAPAN], and **Gay Perez** [Philippines Space Agency]. **Photo credit:** Meghavi Prashnani

urban areas, and smallholder agriculture systems. She emphasized that the new, very-high-resolution data and new sensors [e.g., NASA's Global Ecosystem Dynamics Investigation (GEDI)⁸ mission]—along with strong scientific partnerships and collaborations developed during SARI—have the potential to address these issues.

Updates from Regional Space Agencies

Representatives from six regional space agencies in South and Southeast Asia also gave updates on their agency's activities. The organizations included the Indian Space Research Organization (ISRO), Vietnam National Space Center (VNSC), Thai Geo-Informatics and Space Technology Development Agency (GISTDA), Japan Aerospace Exploration Agency (JAXA), Philippines Space Agency (PhilSA), and the Indonesian National Institute of Aeronautics and Space [Lembaga Penerbangan dan Antariksa Nasional (LAPAN)]. (These speakers are shown and named in **Photo 3**.)

Panel Discussion Toward SARI Synthesis

Chris Justice and **Krishna Vadrevu** moderated a panel discussion called "Toward SARI Synthesis." To date, there have been 22 SARI projects completed. The purpose of this discussion was to plan for the next stage of analysis called *SARI synthesis*. The panel consisted of experts of LCLUC science in the SARI region. **Karen Seto** [Yale University], **David Skole** [Michigan State University], and **Atul Jain** [University of Illinois Urbana Champaign] represented activities in South Asia. **Peter Potapov** [UMD], **Son Nghiem** [JPL], and **Arianne De Bremond** [UMD] represented activities in Southeast Asia.

Each panelist was asked to share his or her unique perspective on moving toward SARI Synthesis and to answer the following questions: *What is your perspective on moving toward SARI Synthesis? What do you see as the biggest challenge in terms of advancing land use change science in the region? What would you like to see happen?*

⁸ GEDI is a space-based lidar that is mounted on the International Space Station. For more information, visit <https://gedi.umd.edu>.

There was a common theme in the responses from panelists that land use studies in this region should be conceptualized from a South and Southeast Asian perspective as opposed to following western prototypes. Additionally, the panelists were unanimous in their assessment that synthesis needs to occur through interdisciplinary studies of diverse domains of Earth science—e.g., ecology, hydrology, geophysics, geochemistry, and atmospheric science. Furthermore, in order to obtain a better environment, equity, land tenure, food security, and wellbeing of society, the physical aspects of land-use change mentioned above must be studied in conjunction with human dimensions of the issue. So, the consensus arising from the discussion was that there is a need for an integrated science-driven approach with a regional outlook involving and encouraging regional scientists. The panelists stressed the importance of strengthening urban studies in the SARI region. Additionally, they noted that there has been a rapid and massive expansion of infrastructure, dams, roads, solar energy installations, canals, and railways in the SARI region; hence, SARI projects can help study the cause and impacts of these land-use changes.

DAY THREE

The third day featured the third invited presentation from NASA HQ, followed by project introductions from the recent 2019 LCLUC selections involving Early Career Scientists (ECS), followed by a discussion on the international Global Observations of Forest Cover and Land-use Dynamics (GOF-C-GOLD) program⁹ and the LCLUC future directions. **Garik Gutman** moderated all sessions.

Invited NASA HQ Presentation

Sandra Cauffman [NASA HQ—*Deputy Director of the ESD*] discussed the significance of the LCLUC program within the ESD and how products and information from LCLUC projects have been providing useful solutions to the demands of national and

⁹ GOF-C-GOLD is an integrated project within the program Global Terrestrial Observing System (GTOS), which is supported by Integrated Global Observing Strategy (IGOS). The project's main objective is to provide a forum for sharing international information, observation and coordination of data, and establishing a structure for monitoring long-term systems.

international agencies, such as the U.S. Agency for International Development (USAID), U.S. Department of Agriculture (USDA), and U.S. Forest Service. The LCLUC program is successfully addressing problems that are of societal relevance and impetus for understanding the sustainability, vulnerability, and resilience of human land-use and terrestrial ecosystems. The program is unique and its strength lies in integrating physical and social sciences to understand land-use change processes at various spatial scales.

Presentations from Early Career Scientists

Garik Gutman began the session with a brief introduction of the nine new LCLUC projects¹⁰ and their investigators from the ROSES 2019 selections,¹¹ which was a call for Early Career Scientists. Gutman gave a brief overview of the program, explaining to the new PIs about the LCLUC website's features and how their projects should strengthen the GOFc–GOLD regional networks involving local researchers. Gutman emphasized that the project metadata are vital for the Program, and that PIs are required to submit their project's metadata. There is an existing LCLUC metadata page on the program website, and a metadata sub-portal will soon be developed to improve metadata searching.

After Gutman spoke, each of the early career LCLUC PIs gave presentations, elaborating on the objectives and expected outcomes of their specific projects as well as their societal relevance. These new projects aim to investigate a variety of themes in land use science such as agriculture, forests, climate change, food security, market forces, and biodiversity, as well as their socioeconomic drivers and impacts. These recent nine LCLUC 2019 selections will contribute to the regional GOFc–GOLD networks.¹² Several of them fall under the Red Latinoamericana de Teledetección e Incendios Forestales (RedLaTIF) regional network, which covers Latin America. New PIs are requested to strengthen the GOFc–GOLD network in their project region through collaborating with local scientists.

Discussion on Future Directions for LCLUC Program

Chris Justice gave a presentation on the Program's future direction to set the tone for a discussion among participants. The use of very-high-resolution data and integration of data from different satellite systems, such as the Harmonized Landsat Sentinel (HLS) project,

¹⁰ These 2020 projects are listed along with all other current and past LCLUC projects at <https://lcluc.umd.edu/content/projects>. Click on the *South Asia* and *Southeast Asia* tabs to see the specific projects in these regions.

¹¹ For more information on this call, see <https://nspires.nasaprs.com/external/solicitations/summary/init.do?solId=%7B716BCFE6-52B4-DB7F-B79A-59F3E7EE14A2%7D&path=open>.

¹² For more information on the GOFc–GOLD networks, including a map showing them all geographically, see <https://gofgold.umd.edu/regional-networks>.

will continue to be developed. The program would like to see products prototyped by MuSLI and transition to operational production. Connections between LCLUC and the NASA Applied Sciences Program will likely be strengthened, and it's likely that the impacts of climate change on land-use will receive more attention. The discussion participants concurred that there is a need for a plan to develop another regional initiative post SARI, based on solid scientific rationale. A couple of regional meetings might help scope such an initiative and inform future solicitations. Suggestions included Latin America and sub-Saharan Africa. There was a discussion on designing a SARI synthesis by a panel of eminent scientists and innovators in LCLUC science in the South and Southeast Asian region. They suggested that the SARI synthesis be framed in the context of existing SARI research undertaken by U.S. and the national and international scientists working in the region.

Conclusion

The meeting concluded with final remarks from **Garik Gutman**. The next Research Opportunities in Space and Earth Sciences (ROSES) call will also target early-career scientists and will follow a two-step solicitation process. The focus will be on the detection and assessment of hotspots via the MuSLI approach. A hotspot in this context is defined as a rapidly changing land-use/cover activity in a particular region over the last several years, characterized by societal significance and impacts, and national to regional importance. The goal is to expand the global hotspot inventory of the LCLUC program. More information about this solicitation can be found in ROSES 2021, to be published in mid-February 2021. The three-day 2020 Science Team Meeting was the Program's first virtual meeting. Participants requested to have a virtual option in future meetings. Next year, the LCLUC Program will be celebrating its 25th Anniversary with current researchers and alumni from the quarter century LCLUC journey. The 2020 Science Team Meeting successfully brought together LCLUC researchers from the U.S. and elsewhere around the world to report on research progress, strengthen partnerships and collaborations, highlight ongoing LCLUC issues, and address community concerns. During the meeting, NASA HQ representatives echoed, that for the rapid advancement of space science, it is crucial to bring science together from corners of the world through collaboration, open science, easy data sharing, and incentive programs—despite political distractions and conflicts. They also emphasized that NASA is highly committed to inclusive, equitable, accessible, and diverse work environments. Inclusion has taken its place alongside safety, integrity, teamwork, and excellence, as the fifth core value of the agency. ■