ICESat-2 Applications Vegetation Tutorial with Landsat 8 Report

Meeting Hosted by University of Michigan
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Workshop Objectives and Summary

The Ice, Cloud and land Elevation Satellite-2 (ICESat-2) mission applications team held a joint mission tutorial with Landsat 8 on May 7 and 8 at the University of Michigan in Ann Arbor, as part of the ICESat-2 Applications plan to broaden and engage the user community for mission data products prior to launch. The ICESat-2 Earth observing satellite, scheduled for launch in October 2017, is the next-generation successor to the original ICESat laser altimeter satellite, which provided high-resolution ice, cloud, aerosol, and land elevation data from space. In contrast to the design of the first ICESat mission, ICESat-2 will use a micro-pulse multi-beam instrument—the Advanced Topographic Laser Altimeter System or ATLAS—that will enable improved elevation observations over high slope and rough areas leading to improved detection of changing sea and land ice, as well as improved information on vegetation structure, inland water, ocean elevation, and land elevation. The data from ICESat-2 will be useful to a broad community of scientists, decision makers and policy makers in a variety of fields.

In vegetated areas, dense canopy can prevent laser light penetration to the underlying ground. Elevation measurements of the ground underneath dense canopy will have limited accuracy primarily due to the surface obscuration by vegetation, at the low laser power (532nm wavelength) used by ICESat-2. Land surface[1] properties, such as elevation, slope, roughness, vegetation height and reflectance, can vary at small spatial scales[2]. By design, ICESat-2 is optimized for measuring elevation of snow and ice-covered surfaces rather than characterizing vegetated surfaces. The small footprint, and high pulse rate designed for ICESat-2 are improvements over other space lidar designs but the wavelength and laser power will have some limitations on data quality for vegetated surfaces. Nevertheless, ICESat-2 is expected to resolve tree canopy heights on a global basis providing inputs to the estimation of above-ground biomass and standing carbon stocks. These measurements fill a critical gap in the current state of knowledge in carbon science and will allow scientists to have a much better understanding of how carbon cycles through the Earth system. Because of the novel nature of ATLAS and ICESat-2 data, early engagement with the vegetation community is essential.

[1] Land surface is considered to be the surface absent any overlying vegetation (living or dead) or cultural features. http://www.csr.utexas.edu/glas/pdf/WFAtbd_v5_02011Sept.pdf
[2]Brenner, Zwally, Bentley, Csatho, Harding et al (2011) http://www.csr.utexas.edu/glas/pdf/WFAtbd_v5_02011Sept.pdf

In an effort to improve the utility and use of the ICESat-2 vegetation products, the ICESat-2 applications team has worked closely with vegetation data users and stakeholders to discuss research and potential applications of ICESat-2 data. By discussing the strengths and weaknesses of ATLAS data over varied vegetation types, participants worked to better understand how the data might be used to meet the objectives of the vegetation user community. The ICESat-2 Applications team explored synergistic opportunities for joining the ICESat-2 vegetation lidar data with the optical data from Landsat 8 to motivate product(s) that will use the high precision capabilities from ICESat-2 to create more detailed coverage maps of vegetation canopy cover, density and biomass estimates in the future.

The ICESat-2 Applications Team Deputy coordinator, Vanessa Escobar and the ICESat-2 Deputy Project Scientist Thomas Neumann, facilitated the tutorial. ICESat-2 Science Definition Team (SDT) member and vegetation data product lead Amy Neuenschwander, ICESat-2 Science Definition Team (SDT) member Michael Jasinski, Landsat 8 Project Scientist Jim Irons, Landsat 7 Project Scientist Jeffery Masek and ICESat-2 Applications Coordinator Molly Brown were also in attendance. A total of 35 people attended this meeting representing user groups in commercial, university, state and federal agencies. A detailed agenda for this event can be found at the end of this report (Appendix A). (A list of participants and their organizations is included in Appendix B and a list of the ICESat-2 Mission Science Definition Team (SDT) is included in Appendix C.

The goals of the workshop were to:

- Describe mission goals and products.
- Motivate research using MABEL (the airborne ICESat-2 simulator) and simulated ICESat-2 data by the science community to meet stakeholder needs post-launch.
- Increase the collaboration opportunities with the vegetation community user groups and identify common challenges and needs.
- Explore potential joint mission vegetation products and motivate joint mission efforts with Landsat 8.

Expected Workshop Outcome

The purpose of this workshop was to strengthen the vegetation community's understanding of and potential uses for ICESat-2 vegetation data for decision making. An additional purpose was also to identify and create support for potential joint ICESat-2 and Landsat 8 data products that could be developed by the end user and provide value to the ecosystems science product developer and user community. We examined the possibility of joining Landsat and ICESat-2 data products by analyzing the local needs for the vegetation community, assessing the existing data products used by the community and conceptualizing how Landsat and ICEsat-2 could work together to address key issues described during the meeting.

Through a series of discussion panels, the event identified synergistic ways to join optical data from Landsat and the photon-counting lidar from ICESat-2 for applications in land

management, forest management, vegetation cover and biomass estimates. The tutorial discussed fitting specific data requirements such as format, scale and resolution to the existing Landsat products. Integrating along-track ICESat-2 lidar data with gridded information from Landsat ideally will increase the ease of use and motivate innovative applications in the biosphere using products from existing missions while exploring the possibilities of using future mission products together.

Early Adopter presentations and findings

The ICESat-2 Early Adopter Program was initiated by the mission in 2012 and promotes applications research for the mission to provide a fundamental understanding of how ICESat-2 data products can be scaled and integrated into organizations' policy, business, and management activities to improve decision-making efforts. The ICESat-2 Early Adopter program aims to accelerate the integration of ICESat-2 products after launch of the satellite by providing specific support to Early Adopters who commit to engage in pre-launch research that will enable integration of ICESat-2 data in their applications.

During the Tutorial two of the ICESat-2 mission Early Adopters (Nancy Glenn and Lynn Abbott) presented their Early Adopter projects and discussed early research findings.

1. *Nancy Glenn: Joining ICESat-2 and Landsat 8 for identification of low-lying vegetation.*
   Nancy Glenn (Researcher from Boise Center Aerospace Laboratory and an ICESat-2 Early Adopter) gave a presentation on her early adopter research discussing the remote sensing technologies tuned to semiarid ecosystems for estimating the global carbon budget. Nancy Glen and her research group from Boise Center Aerospace Lab are interested in quantifying and monitoring the change in sagebrush ecosystems that results from fire-grass recurring cycles and that transforms the landscape from intact to invasive annuals. Nancy performed her own simulation of the ICESat-2 data before MABEL was available for her study to gain perspective of the extent to which invasive annuals adapt more quickly than native plant communities. This can inform various management questions (e.g. sage-grouse habitat corridors vulnerabilities) for soil erosion, ecosystem services and urban growth. Nancy sees an opportunity in using different sensors (e.g. Landsat 8 and ICESat-2) to map the different important functional characteristics of the sagebrush ecosystem, i.e. shrub cover, grass cover and bare ground. Her interest in ICESat-2 is to take the information and relationships collected at the fine scale ultimately up to the landscape scale so as to get landscape scale biomass estimates. She identified the height of low-lying vegetation in semiarid ecosystems that may benefit from ICESat-2 data: low sage species (30cm in height), sagebrush (~2m) and average sage brush height in the area of study (~1m). It's important to note that the simulations done by Nancy and her team did not include noise or the point spread function of the ATLAS instrument, so there is a strong expectation from the mission that the species

height numbers detected by Nancy will be lower than reported when the ICESat-2 data are used after the mission launches.
Using her research, Nancy has developed an ICESat-2 simulation (Table 1):

- The contribution of Landsat 8 for shrub cover estimates potentially increases with decreasing point density.
- ICESat-2 simulated point density and footprint distribution and mean shrub heights have a strong similarity to airborne lidar (R2 = 0.60)
- The ICESat-2 simulated point density predicted shrub well (R2= 0.62) and underestimated shrub biomass. Her results bearing a strong similarity to airborne lidar

Variable	*ICESat-2*	*Landsat 8*
Shrub Cover	*X*	*(X)*
Shrub Height	*X*	
Shrub Biomass	*X*	*(X)*
Grass Cover		*X*
Bare Ground Cover		*X*

2. *Lynn Abbott: Estimating Forest Canopy Heights using Photon Counting Lidar.*

Lynn Abbott (Virginia Tech) presented on his group's Early Adopter research. Lynn's team is working to identify canopy and ground surface photons from the photon cloud using a "Snakes" approach, an active contour modeling technique that models curves based on a set of points(?) in a plane. By examining different approaches for contour detection, his group has found a promising method to distinguish ground from top of canopy (TOC) from the photon cloud using test data from Sigma Space MPL and MABEL. His research will help improve Landsat-based maps for the Department of Forest Resources and Environmental Conservation at Virginia Tech by using his use physics-based modeling to improve ground and top of canopy vegetation characterization.

Tutorial Accomplishments

The ICESat-2/Landsat joint mission tutorial gave attendees and the mission representatives the opportunity to expand on ideas presented by speakers, provided a venue for exploring ways to improve the use of mission products and data distribution techniques, and identified interests in potential collaborations for creating working groups, developing future ICESat-2 derived vegetation products, and recommending joint Landsat-8/ICESat-2 experimental products.

Community suggestions for joint products

1. *A variable along track resolution for ICESat-2 data segment will allow users to*

scale ICESat-2 data to application specific resolutions.

Amy Neuenschwander (ICESat-2 Science Definition Team member) made recommendations to simplify the fusion of Landsat and ICESat-2:

- ICESat-2 will produce a variable length along track product that is dependent upon the number of signal photons. The resolution will likely vary from 30 m – 100 m (i.e. hectare) which is the minimum mapping unit used for forestry applications.
- ICESat-2 will produce a global terrain elevation gridded product.
- ICESat-2 will produce a global canopy height gridded product.
- ICESat-2 will produce a global relative canopy cover gridded product
- NDVI derived from Landsat (if timely) could factor into the canopy/surface finding algorithm and be(?) included on for the ICESat-2 along-track products

2. *Using ICESat-2 for Forest Inventory and Analysis (FIA) National Program*

Sorin Popescu (Texas A&M University) pointed out that the ICESat-2 footprint diameter complemented the 14.6m subplot size of FIA inventory, which could help introduce new ways of extending FIA inventory estimates to larger areas. Wenge Ni-Meister, research scientist at NASA Goddard and Hunter College CUNY, has developed a tool to integrate NASA satellite data and FIA data in order to downscale vegetation data (height structure data, biomass, vegetation change) to 30m resolution. She has been nominated to be an Early Adopter for the ICESat-2 mission and is working with Sean Healy, USDA Forest Service.

3. *Biomass Maps and vegetation dynamics*

ICESat-2 and Landsat provide complementary measurements; such as land cover density maps. The structure information derived from ICESat-2, FIA inventory plots, and the stratification from Landsat could be used to address the static mapping challenges to create more accurate above ground biomass maps (Jeff Masek). The use of ICESat-2 data will also help better define the losses due to disturbances, gains in vegetation due to regrowth and compositional changes in land cover. The complements between both missions are a strong opportunity for new science where the modalities of each instrument are leveraged to do what they do best:

- Passive optical radar for sparse forest (boreal and savannah)
- ATLAS for moderately dense forest, steep terrain.
- Landsat for temporal dynamics

4. *Biomass Working Group*

During Panel discussions there were suggestions to develop a working group for biomass using a joined Landsat and ICESat-2 product. The USGS expressed interest in creating an ICESat-2 Biomass Working Group to include products and

researchers from Michigan Technical Research Institute, the USDA Forest Service, USGS, members of the CMS Initiative, Landsat 8 mission, and others.

The ICESat-2 mission will continue follow up discussions with the attendees of the ICESat-2/Landsat Joint Mission Tutorial to ensure the continuity of the proposed products and to ensure mission data are used to their highest potential. We will report on other potential application products proposed by the tutorial attendees as well. These products remain in an exploratory discussion phase and need to have a user and institution identified to lead the development. The ICESat-2 Applications Team coordinators continue to explore opportunities and will report on progress as they develop.

Workshop Outcomes

Presenters were asked to provide a closing slide that identified how synthesizing ICESat-2 and Landsat products would be useful to their applications. The dialog of the meeting built upon these ideas, guidance with the ICESat-2 mission, the ICESat-2 Applications Team and to the user community to identify *how* engagement and collaboration could accelerate and enhance the use of the ICESat-2 vegetation product.

From the ICESat-2 Applications Team

The ICESat-2 Applications Team will take the lead for continued engagement identifying leads for joint product development. The request for mission information such as (1) an overview of product uncertainty, a document that will describe the ICESat-2 product uncertainty relevant to vegetation and explain what the relative errors are in height estimates; and (2) information on the vegetation community stakeholders, which will be provided to the community and posted to the ICESat-2 Data Products page. The Mission and the Mission applications team will provide regularly updated information on mission products and communicate news via emails to the ICESat-2 Applied Sciences Community.

From NASA Headquarters

Attendees request funding opportunities from NASA Headquarters for developing feasibility studies for above ground biomass (Landsat 8 and ICESat-2) and joint products (such as a NASA MEASURES proposal for joining ICESat, Landsat and ICESat-2). In addition, there was a request for collaboration with the USGS to develop a vegetation/biomass-working group that will help define products that are most useful to the community and demonstrate the transition of products from research to operations.

Conclusions

Mission application engagement aims to work across boundaries and join the science development of products to the practical applications for society. This ICESat-2 mission

vegetation tutorial's goal was to identify synergies and advance the knowledge and awareness of the ICESat-2 mission data product so that after launch applications will move rapidly in areas already explored during the prelaunch.

Our host from the University of Michigan concluded that at the onset of the workshop she was "unsure as to how ICESat-2 and Landsat would be able to be conceptualized in a cohesive way. The workshop made that connection quite apparent and the workshop presentations and discussions lead us all to fully recognize the complementary nature of the two systems". This meeting was a unique opportunity bringing "together two remote sensing groups that are not always collaborating - the 'operational satellite' folks and the 'science satellite' folks."

Mission tutorials, focus sessions and workshops are strategies the Mission Application Team uses to engage with the user community. Feedback on mission product applications is welcomed at all times and will be communicated to the mission in an effort to broaden the ICESat-2 user community (Community of Practice) and identifying innovative ways of applying mission products to societally relevant cases. Opportunities for engagement, future events and Early Adopter opportunities can be found at http://icesat.gsfc.nasa.gov/icesat2/apps-ov.php.

Appendix A

ICESat-2 Applications Vegetation Tutorial with Landsat 8
Hosted by
University of Michigan
Samuel T. Dana Natural Resources Building
Ann Arbor, Michigan
May 7-8, 2014

The ICESat-2 Vegetation Tutorial with Landsat 8 opens a unique opportunity to discuss innovative ways of combining data sets from both the ICESat-2 and Landsat 8 missions. The main focus of the tutorial is to create an open-dialogue on how multi-mission data users can develop new joint vegetation products and to explore how these can be best utilized.

Goals of the ICESat-2 Vegetation Tutorial with Landsat 8:

- Communicate the goals and describe the products of both the ICESat-2 and Landsat 8 missions
- Increase collaboration opportunities with user groups by identifying the challenges and needs of the vegetation user community
- Explore potential joint-mission vegetation products and motivate joint mission efforts with Landsat 8

Expected Workshop Outcome: Identify and create support for potential joint ICESat-2 and Landsat 8 data products that would be of value to the vegetation community.

7 MAY WEDNESDAY		
8:00am	Registration and Coffee	
8:30am	*Dan Brown, University of Michigan {20 min}*	Tutorial Welcome
8:50am	*Tom Neumann, Deputy ICESat-2 Mission Project Scientist {20 min}*	Tutorial Objectives, ICESat-2 Mission Overview, & ICESat-2 Data Products
9:10am	*Jim Irons, Landsat Mission Project Scientist {20 min}*	Landsat 8 Mission Overview and Synergies with ICESat-2
9:30am	*Mike Jasinski, ICESat-2 Science Definition Team (SDT) Liaison {15 min}*	Early Adopter datasets and MABEL
9:45am	*Vanessa Escobar, ICESat-2 Applications Deputy Coordinator {20 min}*	Mission Applications and Strategy for Tutorials
10:10am	**Morning Break**	
10:30am	*Amy Neuenschwander, ICESat-2 SDT & University of Texas at Austin {30 min}*	ICESat-2 vegetation product, State of current ICESat-2 retrieval algorithms, & Comparison of ICESat and ICESat-2 data
11:00am	*Paul Montesano, NASA Goddard Space Flight Center (GSFC) {20 min}*	The uncertainty of biomass estimates from modeled ICESat-2 returns across a boreal forest gradient
11:20am	*Thomas Loveland, Landsat Science Team & U.S. Geological Survey (USGS) {20 min}*	Landsat 8 products and applications

11:40am	Q & A Session: ICESat-2 and Landsat Vegetation Products (*Tom Neumann, Mike Jasinski, Amy Neuenschwander, Paul Montesano, & Thomas Loveland*)	
12:00pm	**LUNCH 12:00-1:30pm** **Poster Session During Lunch**	
1:30pm	*Jim Vogelmann, Landsat Science Team & USGS {20 min}*	Large area land cover monitoring: Current status and new opportunities
1:50pm	*Kathleen Bergen, University of Michigan {20 min}*	Synergy of Lidar and optical for biodiversity and habitat mapping
2:10pm	*Leland Pierce, University of Michigan {20 min}*	Electromagnetic modeling for Lidar and Landsat remote sensing of forests
2:30pm	*Laura Bourgeau-Chavez, Michigan Tech Research Institute {20 min}*	Detection of forested wetlands with active remote sensing
2:50pm	**Afternoon Break**	
3:10pm	*Warren Cohen, Landsat Science Team & USDA Forest Service {20 min}*	Using Landsat to monitor forest disturbance
3:30pm	*Sean Healey, USDA Forest Service {20 min}*	Integration of ICESat-based forest inventory results with Landsat-based vegetation and disturbance maps
3:50pm	*Sorin Popescu, Texas A&M University {20 min}*	Estimating forest biophysical parameters using ICESat-1 & 2 Lidar datasets
4:10pm	*Tom Neumann, ICESat-2 Mission Deputy Scientist {30 min}*	Q&A / Closing Remarks
4:45pm	**Day 1 Adjourned** **Poster Session until 5:30pm** **Social Dinner to follow Poster Session**	
8 MAY THURSDAY		
8:00am	Registration and Coffee	
8:30am	*Vanessa Escobar, ICESat-2 Applications Deputy Coordinator {20 min}*	Recap of Day 1, Objectives for Day 2, & ICESat-2 Early Adopter Program
8:50am	*Nancy Glenn, Boise Center Aerospace Laboratory {20 min}*	Improved terrestrial carbon estimates with semiarid ecosystem structure
9:10am	*Lynn Abbott, Virginia Polytechnic Institute and State University {20 min}*	Detection of ground and top of canopy using simulated ICESat-2 Lidar data
9:30am	*Jeffrey Masek, NASA GSFC {20 min}*	Using ICESat-2 and Landsat 8 data together to characterize vegetation
9:50am	**Morning Break**	
10:20am	Panel Discussion/Audience Discussion *Open discussion – Identify potential collaborations and opportunities* *(Molly Brown, Amy Neuenschwander, Warren Cohen, Sean Healey, Jeffrey Masek, Nancy Glenn, & Birgit Peterson)*	
11:20am	*Tom Neumann & Mike Jasinski, ICESat-2 Mission Team {20 min}*	• Review Tutorial objectives & successes • Identify common themes from Tutorial • Mission and Early Adopter timeline • Identify relevant 2014 ROSES solicitations
11:40am	*Vanessa Escobar {20 min}*	Closing Remarks & Announcements
12:00pm	**Tutorial Adjourned**	

Appendix B

ICESat-2 Applications Vegetation Tutorial with Landsat
Ann Arbor, MI
May 7-8, 2014

First	Last	Organization	Research Interest (primary)	Research Interest (secondary)
Lynn	Abbott	Virginia Tech	Applications	Vegetation
Elizabeth	Agee	University of Michigan	Water Resources	ecohydrology
Amanda	Armstrong	ORAU- GSFC	Ecological Forecasting	vegetation
Don	Atwood	MTU - MTRI	Ecological Forecasting	Biomass
Don	Atwood	MTU-MTRI	Applications	SAR
Chad	Babcock	Michigan State University	Ecological Forecasting	Forest Science
Michael	Battaglia	MTRI	Water Resources	Vegetation
Kathleen	Bergen	Research Scientist	Ecological Forecasting	land-cover/land-use
Laura	Bourgeau-Chavez	Michigan Tech Research Institute	Ecological Forecasting	vegetation
Andrew	Brenner	Quantum Spatial		
Dan	Brown	University of Michigan	Ecological Forecasting	land use
Molly	Brown	NASA Goddard Space Flight Center	Applications	food security
Warren	Cohen	USDA Forest Service	Applications	forest monitoring
Chase	Dwelle	University of Michigan	Agriculture	Agriculture response to climate
Dennis	Dye	U.S. Geological Survey	Climate	vegetation
Arthur	Endsley	Michigan Tech Research Institute	Climate	visualization
Vanessa	Escobar	NASA Goddard Space Flight Center	Water Resources	Health
Nancy	French	Michigan Tech Research Institute	Disasters	wildland fire
Yan	Gao	University of Melbourne	Applications	N/A
Nancy	Glenn	Boise State University	Ecological Forecasting	vegetation
Sean	Healey	US Forest Service	Applications	forests
Mark	Higgins	World Resources Institute	Ecological Forecasting	Deforestation monitoring
James	Irons	NASA Goddard Space Flight Center	Agriculture	Landsat
Michael	Jasinski	NASA Goddard Space Flight Center	Water Resources	Research Hydrologist
Kristofer	Johnson	US Forest Service	Ecological Forecasting	forests
Tom	Loveland	U.S. Geological Survey	Climate	land use change
Bristol	Mann	University of Michigan	remote sensing	
Jeffrey	Masek	NASA Goddard Space Flight Center	Ecological Forecasting	vegetation
Jessica	McCarty	Michigan Tech Research Institute	Health & Air Quality	Applied Environmental Science
Mary	Miller	MTRI	Disasters	Post-fire erosion \ LAI \ wildfire
Paul	Montesano	Sigma Space Corp/ NASA GSFC	Applications	vegetation
Amy	Neuenschwander	University of Texas at Austin		
Tom	Neumann	NASA Goddard Space Flight Center	Climate	glaciology
Yong	Pang	Chinese Academy of Forestry	Ecological Forecasting	forest parameter estimation
Alicia	Peduzzi	US Forest Service	Applications	vegetation
Birgit	Peterson	USGS EROS	Disasters	vegetation
Leland	Pierce	University of Michigan	Applications	Forest biomass estimation
Sorin	Popescu	Texas A&M University	Ecological Forecasting	vegetation
Christopher	Potter	NASA Ames Research Center	Applications	vegetation
Amy	Rohman	MTRI	Climate	Fire
Ryan	Sheridan	Texas A&M University	Applications	Vegetation
Neil	Ver Planck	Michigan State University	Ecological Forecasting	Forest vegetation
Jim	Vogelmann	USGS/EROS	Applications	vegetation
Matthew	Whitley	MTRI	Disasters	Fire
Gong	Zhang	NASA Ames Research Center	Ecological Forecasting	Biomass
Kaiguang	Zhao	Ohio State University	Applications	vegetation

Appendix C

ICESat-2 Science Definition Team (SDT)

The ICESat-2 Science Definition Team (SDT) is a group of competitively selected scientists (selected in February 2012) who help with defining the science goals and provide guidance and advice to the ICESat-2 project to ensure the mission meets its science requirements. The ICESat-2 SDT members are:

- Bea Csatho, Univ. at Buffalo: ice sheets, SDT Leader
- Sinead Farrell, ESSIC, UMD: sea ice
- Helen Fricker, Scripps Institution of Oceanography: ice sheets
- Dave Harding, NASA GSFC: solid earth
- Mike Jasinski, NASA GSFC: hydrology
- Ron Kwok, JPL: sea ice
- Michael Lefsky, Colorado State Univ.: vegetation
- Dan Lubin, Scripps Institution of Oceanography: atmospheric science
- James Morison, Univ. of Washington: Arctic oceans
- Ross Nelson, NASA/GSFC: vegetation
- Amy Neuenschwander, Univ. of Texas: vegetation
- Steve Palm, SSAI: atmospheric science
- Bob Schutz, Univ. of Texas: geodesy
- CK Shum, Ohio State Univ.: ice sheets
- Ben Smith, Univ. of Washington: ice sheets
- Jay Zwally, NASA GSFC: ice sheets