CEOS’s Land Product Validation Focus Area on Biomass: Updates

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Kim Calders, Jerome Chave, Keryn Paul, Tommaso Jucker, Jim Kellner, Grant Domke, JF Bastin, Atticus Stovall, Harm Bartholomeus, Nicolas Barbier, Valerio Avitabile, Maxime Réjou-Méchain, Ron McRoberts, Stephen Roxburgh, Eric Næsset, Marcos Longo, Hans Anderson, Martin Herold, Martin de Kauwe, Richard Lucas, George Hurtt, Natasha MacBean, Sarah Carter, Tom Crowther, Mike Falkowski, Oliver Phillips, Mat Williams, Clément Albinet, many more ....
Many Upcoming Missions Will Provide Data That Will Be Used to Map Biomass

<table>
<thead>
<tr>
<th>Mission</th>
<th>Funding Agency</th>
<th>Expected Launch Date</th>
<th>Data Type</th>
<th>Biomass Product Resolution</th>
<th>Geographic Domain</th>
<th>Accuracy Requirement</th>
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</thead>
<tbody>
<tr>
<td>NISAR</td>
<td>NASA/ISRO</td>
<td>2021/2022</td>
<td>L-band SAR</td>
<td>1 ha (&lt;100 Mg/ha)</td>
<td>Global</td>
<td>&lt;20% RMS accuracy for &lt;100 Mg/ha</td>
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<tr>
<td>GEDI</td>
<td>NASA</td>
<td>Dec 5, 2018</td>
<td>1064 nm waveform lidar</td>
<td>1 km</td>
<td>ISS (+/- ~51.6°)</td>
<td>&lt;20% SE for 80% of forested 1 km cells</td>
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<tr>
<td>BIOMASS</td>
<td>ESA</td>
<td>2022</td>
<td>P-band SAR</td>
<td>4 ha</td>
<td>Global (minus defense issues)</td>
<td>Accuracy of 20%; 10 Mg/ha for &lt;50 Mg/ha</td>
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<tr>
<td>MOLI</td>
<td>JAXA</td>
<td>2020?</td>
<td>1064 nm waveform lidar</td>
<td>500 m</td>
<td>ISS (+/- ~51.6°)</td>
<td>NA</td>
</tr>
<tr>
<td>SAOCOM 1A</td>
<td>CONAE</td>
<td>October 8, 2019</td>
<td>L-band SAR</td>
<td>NA</td>
<td>Global</td>
<td>NA</td>
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<tr>
<td>ICESat-2</td>
<td>NASA</td>
<td>Sept 15, 2018</td>
<td>532 nm photon counting lidar</td>
<td>NA</td>
<td>Global</td>
<td>Global</td>
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<tr>
<td>TanDEM-L</td>
<td>DLR</td>
<td>2022-2023?</td>
<td>L-band SAR</td>
<td>1 ha</td>
<td>Global</td>
<td>20% accuracy or 20 Mg/ha</td>
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## Components of CEOS LPV Biomass Protocol

The protocol will be a good practices guide to biomass model calibration and product validation at a global (or near global) scale

<table>
<thead>
<tr>
<th>Good practices for biomass estimation in the field</th>
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<tbody>
<tr>
<td>• Allometric Error</td>
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<td>• Field Measurement Error</td>
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<td>• Terrestrial Laser Scanning</td>
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<tr>
<th>Linking remote sensing observations to field estimates</th>
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<tbody>
<tr>
<td>• Geolocation &amp; Spatial Scale</td>
</tr>
<tr>
<td>• Using airborne data to scale from field to spaceborne data</td>
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<table>
<thead>
<tr>
<th>Error Propagation</th>
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<tr>
<td>• Sources of Uncertainty</td>
</tr>
<tr>
<td>• Extrapolating models to global maps</td>
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<tr>
<th>Independent Validation and Reporting</th>
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<tbody>
<tr>
<td>• Reporting requirements for each stage</td>
</tr>
<tr>
<td>• Scope/scale of products</td>
</tr>
<tr>
<td>• Error reporting by strata</td>
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<tr>
<th>Recommendations for User-led validation</th>
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<tr>
<td>• Harmonization of definitions</td>
</tr>
<tr>
<td>• Screening of Data</td>
</tr>
<tr>
<td>• Considerations of Scale</td>
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<th>Utility of Protocol for Other Communities</th>
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<tr>
<td>• Modeling community</td>
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<tr>
<td>• Policy communities</td>
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<td>• Non-forest communities</td>
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<th>Knowledge Gaps</th>
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<tr>
<td>• Experiments that will advance the field</td>
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<tr>
<td>• Airborne / Field data gaps</td>
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<tr>
<td>• Cross mission cal/val plans</td>
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<tr>
<td>• Improvement of allometric models</td>
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<tr>
<td>• Development of tools for validation and intercomparison</td>
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CEOS LPV Meeting, Milan, May 2019
Field Biomass Estimation

- There are errors in Field plots estimates of biomass that need to be estimated and propagated from the tree to the plot-level. Uncertainties from:
  - Allometric models
  - Plot location and geometry
  - Tree measurement error (ht, DBH)
  - D:H models
  - Wood density
  - Carbon expansion factors

Figure from Keryn Paul, LPV Biomass Protocol

(1) Within-individual sampling
Sub-samples are selected from individuals to obtain MC_{AGB} based on partitioning of AGB into components.

(2) Among-individual sampling
Sample individuals of a defined strata. This definition may be based on a specific species or group of species, and possibly of specific characteristics, e.g. age, size, and climate.

For each strata of individuals that were sampled for AGB, but which were not also sub-sampled for MC determination, average MC_{AGB} values are applied (e.g. A_A, A_B, A_C, A_D).

(3) Sample size
N individuals are selected for sampling for AGB which were also sub-sampled for MC_{AGB} determination.
Terrestrial Laser Scanning and UAV Lidar

TLS has emerged as a technology useful for a) measuring woody volume and b) re-fitting biomass allometries

TLS and UAV data are new, and attention to errors is critical

Figures from Calders-led LPV Biomass Protocol
Error Estimation in Biomass Maps

Several statistical methods allow error propagation:
- Design-based inference
- Model-based inference
- Design-based, model-assisted
- Hybrid inference

Figure from Steven Ruxburgh and Ron McRoberts LPV Biomass Protocol
User-led Product Validation

New chapter led by Valerio Avitabile

The CEOS Biomass Protocol has a chapter on recommendations for user-led validation using a) Field Plots, b) Regional Statistics, c) Local biomass maps (e.g. from airborne lidar)

We have a series of workflows and suggestions for harmonization, but do not have a tool for user-led validation

• Potential collaboration with FAO? SERVIR?
• Collect Earth, SEPAL, etc.
• (World Bank, SilvaCarbon ...)
General Biomass Validation Concept

Error Propagation

1. TLS and Field Data for plot biomass estimates

2. Calibrate Airborne lidar with \textit{in situ} data

3. Generate local biomass maps at desired (spaceborne product) resolution

4. Report accuracy over geographic domain of interest given available data
What are the user needs of biomass products & validation?

- Modeling Communities
- Policy Applications
- Land Use / Land Cover Change
- ‘Non-forests’ Communities
  - Belowground biomass
  - Woodlands/savannas
  - Biodiversity

Flexibility for validation at multiple spatial resolutions

Flexibility of validation reporting scales / scopes / strata

Consistency of validation with single dataset (reliable, high quality, public, transparent)

Opportunities for promoting user-led validation
# Timeline for Biomass Protocol

<table>
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<tr>
<th>Timeline</th>
<th>Activities</th>
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| Fall 2017              | • Identify contributors  
|                        | • Develop draft protocol skeleton  
|                        | • Meet with writing groups                                                  |
| Winter 2017            | • Finalize skeleton, writing groups / leads                                 |
| 2018                   | • Chapter drafts  
|                        | • Review paper on biomass validation                                        |
| Spring 2019            | • Collation of section drafts  
|                        | • Internal review                                                           |
| Summer 2019            | • Protocol external review                                                  |
| Fall 2019              | • Protocol publication                                                      |
| Winter 2019 and beyond | • Collation of reference datasets  
|                        | • Adoption by ICESAT-2 & GEDI biomass products                              |

New review paper introduces protocol: Duncanson et al., The Importance of Consistent Global Forest Aboveground Biomass Product Validation, *in press*, Surveys in Geophysics
Implementation Considerations

CEOS WGCV LPV Biomass Validation Protocol
Duncanson, Armston, Disney, Nickeson, Roman, many many contributors

CEOS LPV Endorsed Biomass Product Validation

Updated Reference Datasets
Validation Tools
Toward Protocol Implementation

We propose a two-tier implementation of product validation

1) CEOS LPV-led independent validation of products using biomass in situ ‘supersites’
   • Automated and consistent product validation and reporting

2) Stakeholder-led validation using a wide range of available in situ data
   • Collect Earth / Collect Earth Online (FAO, SERVIR)
   • National Forest Inventory data
GEDI’s Field and Lidar Calibration Database

Data are crowd-sourced from international collaborators

Map current as of July, 2018
Multi-Mission Biomass Cal/Val Group

Monthly telecons between members of NASA GEDI, ICESat-2, ESA BIOMASS and NASA/ISRO NISAR team, as well as representatives from plot networks (ForestPlots, ForestGEO, FOS)

- Metadata and Data Sharing
- Airborne and field campaign planning
- Processing workflow harmonization (e.g. field data)
- Development of joint priorities and recommendations
Multi-Mission Biomass Cal/Val Group

**NISAR:**
- Bruce Chapman
- Paul Siquiera
- Victoria Meyer
- Naiara Pinto
- Sassan Saatchi
- Paul Rosen

**BIOMASS:**
- Klaus Scipal
- Shaun Quegan
- Jerome Chave
- Nicolas Labriere
- Clement Albinet

**GEDI:**
- Ralph Dubayah
- Laura Duncanson
- Michelle Hofton
- Lola Fatoyinbo
- John Armston
- David Minor
- Jim Kellner

**MAAP:**
- Marco Lavalle
- Clement Albinet
- Amanda Whitehurst
- Laura Duncanson

**Plot Networks:**
- Stuart Davies
- Oliver Phillips
- Jerome Chave

**Other:**
- Mike Falkowski (NASA HQ)
- Richard Lucas (CCI Biomass)
- Amy Neuenschwander (ICESat-2)
- Mat Disney (UCL, CEOS LPV)
GEDI, ICESat-2, NISAR, and ESA BIOMASS teams are working on coordinated cal/val
Proposed Biomass Validation Supersites

A subset of data rich Multi-Mission Sites that have been identified as serving all missions
GEDI Forest Structure and Biomass Database
Planet data Pilot for Monitoring In Situ Plots

• Reference data are expensive – we want to use as much quality in situ data as possible, including data collected prior to mission collections
  • E.g. can we use a field dataset collected in 2019 to validate a mission product flown in 2022?

• Pilot under way through NASA’s Commercial Data Buy to assess the utility of high spatial and temporal resolution data (Planet) to flag disturbance in reference datasets

• Multi-mission team is collating a list of known disturbed forest plots for this pilot study, comparing results to landsat-based disturbance monitoring
A large wind storm hit La Selva Biological Research Station in May, 2017. Considerable blown down significantly affected the biomass density of many of the reference plots. We have airborne lidar before (and soon after) this event, used to validate our Planet-based disturbance detection algorithms.

https://www.planet.com/stories/la-selva-windstorm-before-after-dMlf_ICmR
Potential for Validation Portal Development Via the Multi-mission Analysis and Algorithm Platform

MAAP will host *public* satellite data (focused on Lidar and SAR), airborne campaign data and field data.

Data and Computing

MAAP

Joint access to data and algorithms

Data and Computing

NASA

esa

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Next Steps

• Add a chapter on biomass *change* validation

• Collection of new field, TLS and airborne lidar over biomass super-sites
  • And/or establishment of new biomass super-sites

• Develop tools for CEOS-led validation (on NASA-ESA MAAP?)

• Explore / Adapt Existing tools for user-led validation

• BRIX2 exercise (led by Clement Albinet, on NASA-ESA MAAP?)
Thank you!