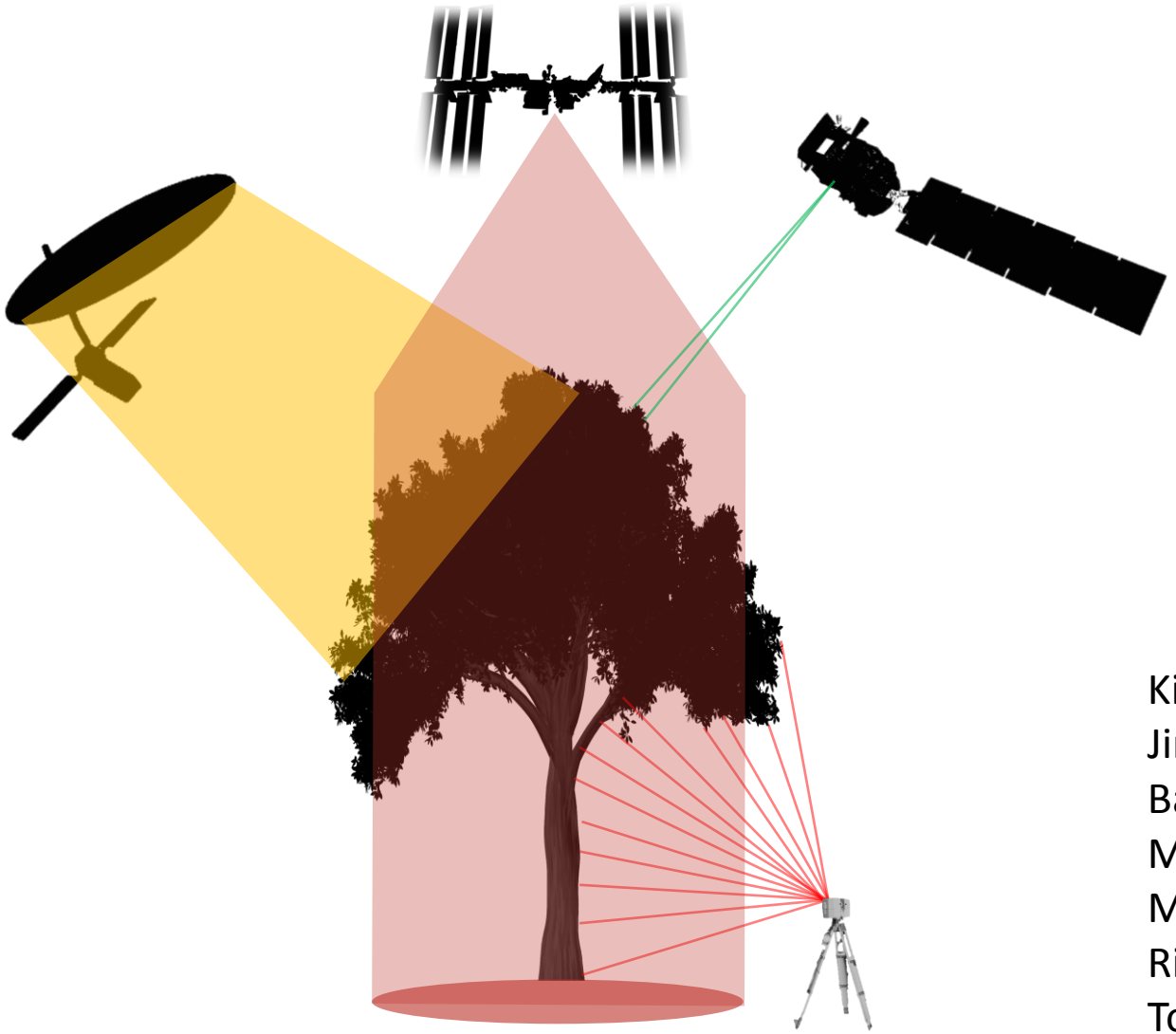


CEOS's Land Product Validation Focus Area on Biomass: Updates

Laura Duncanson, John Armston, Mat Disney

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

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

Components of CEOS LPV Biomass Protocol

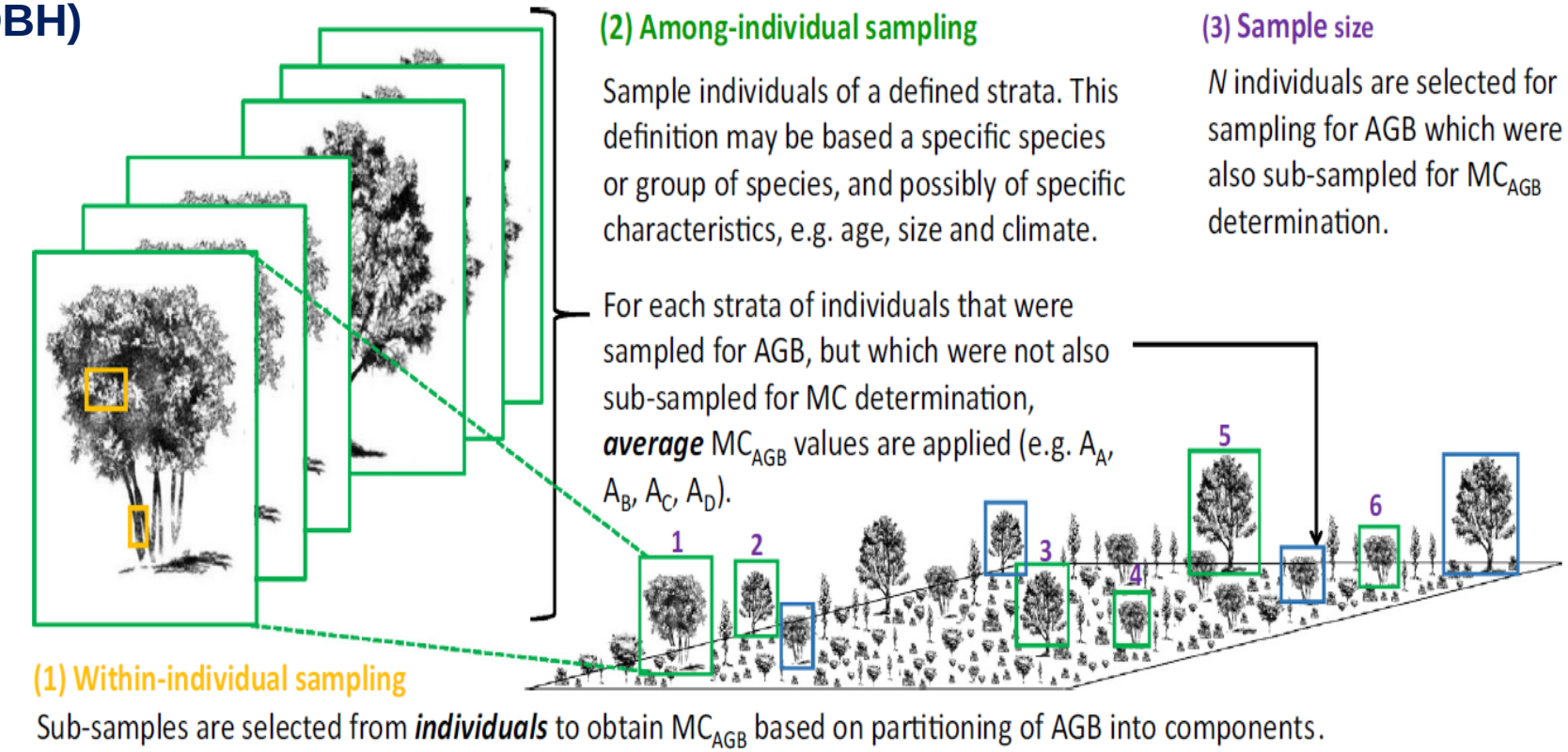
The protocol will be a good practices guide to biomass model calibration and product validation at a global (or near global) scale

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

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**

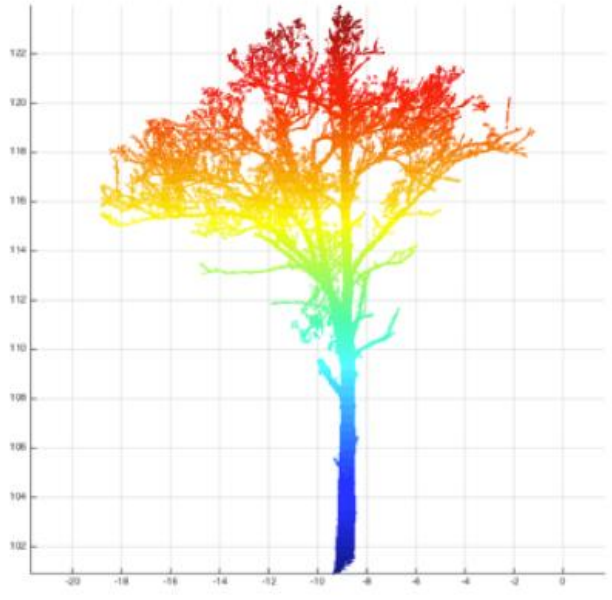
Figure from Keryn Paul, LPV Biomass Protocol

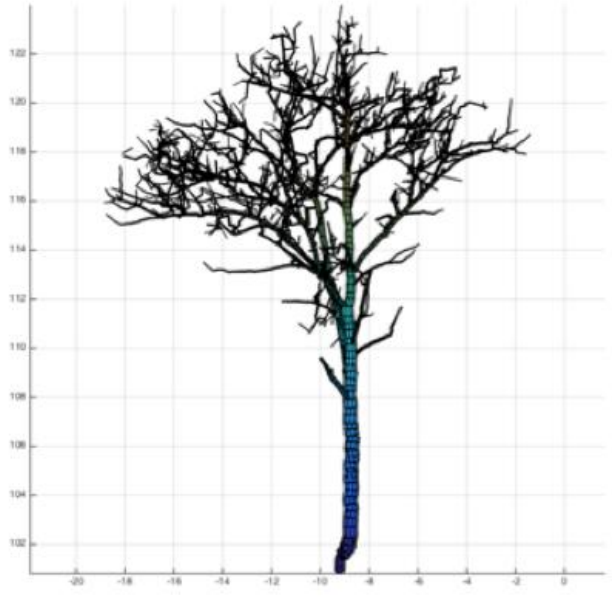


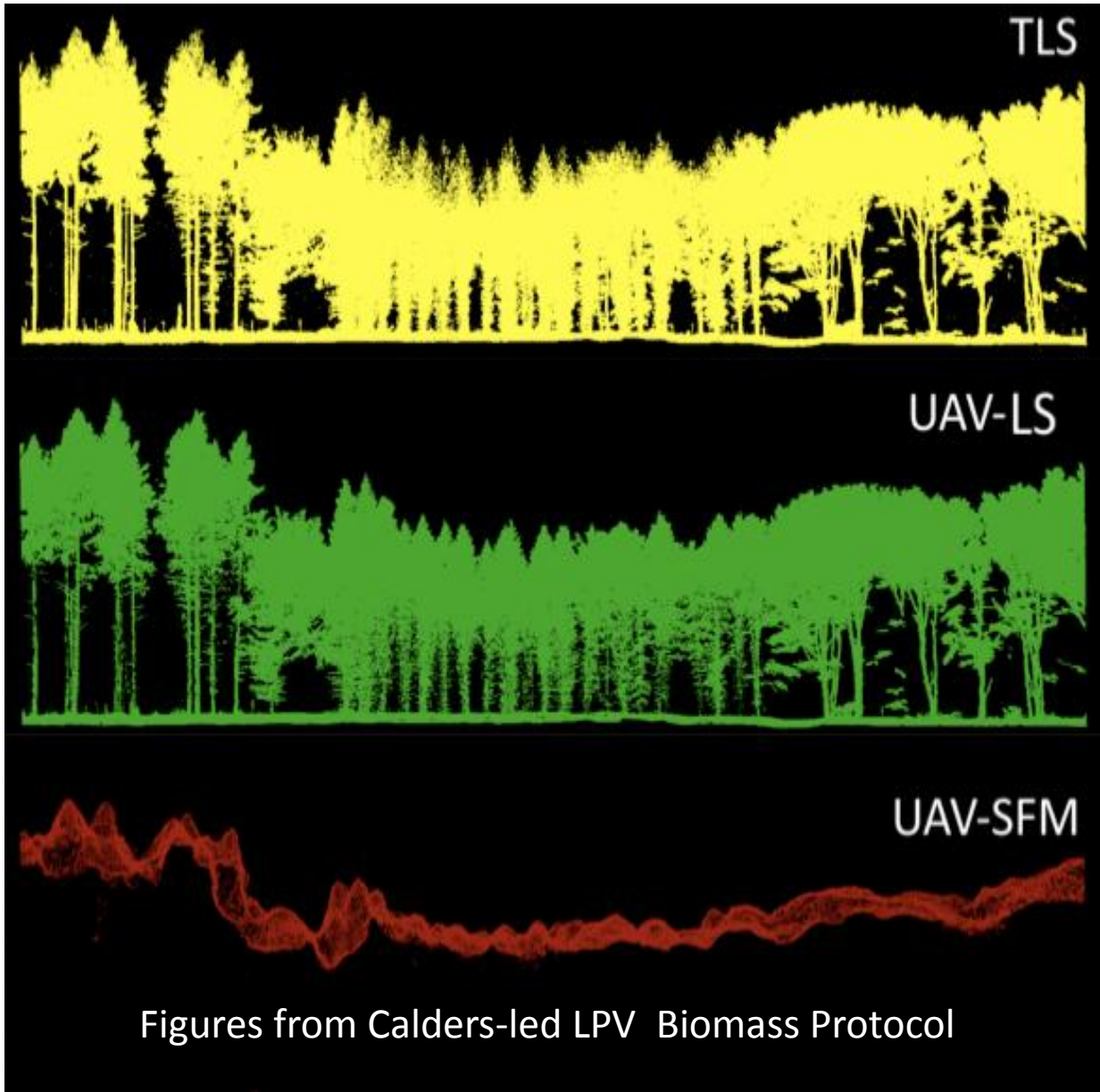
Terrestrial Laser Scanning and UAV Lidar

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







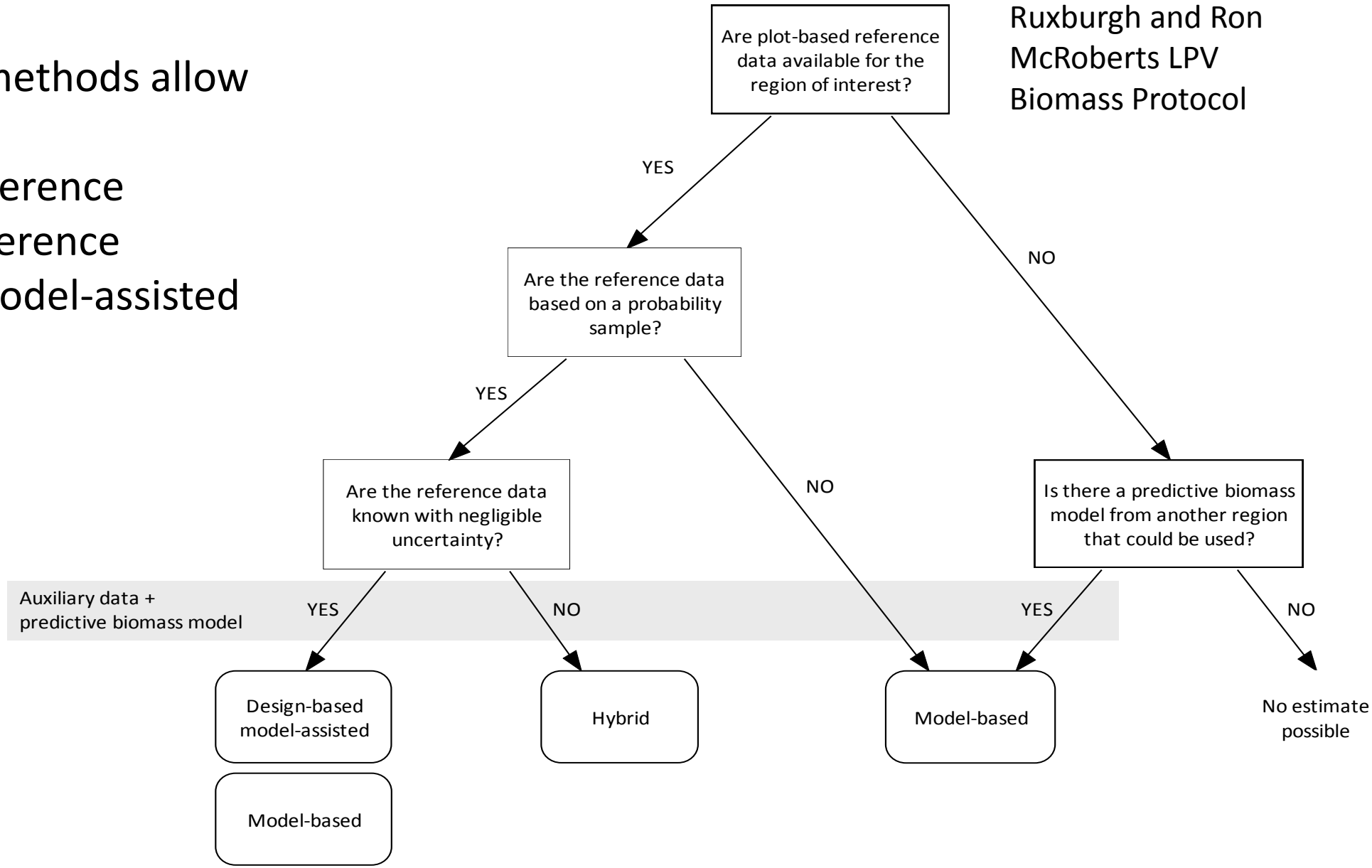
Figures from Calders-led LPV Biomass Protocol

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



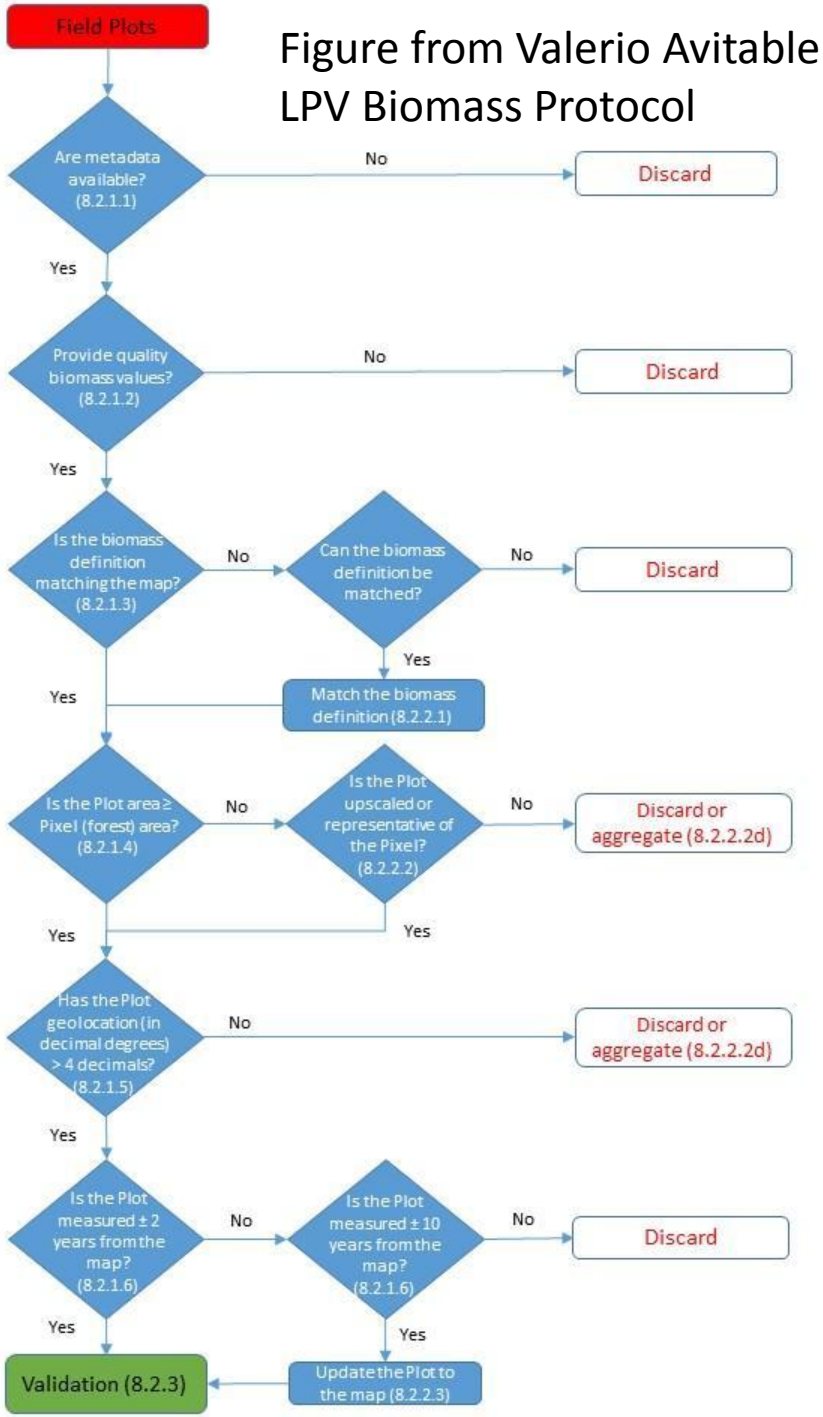
User-led Product Validation

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

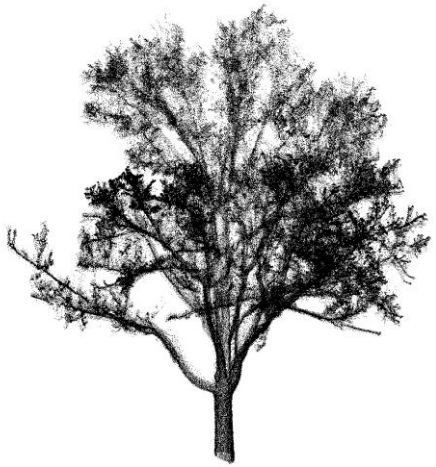
- Potential collaboration with FAO? SERVIR?
- Collect Earth, SEPAL, etc.
- (World Bank, SilvaCarbon …)

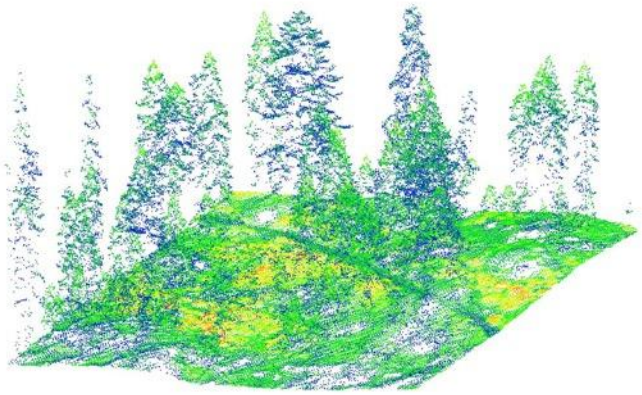


General Biomass Validation Concept

Error Propagation

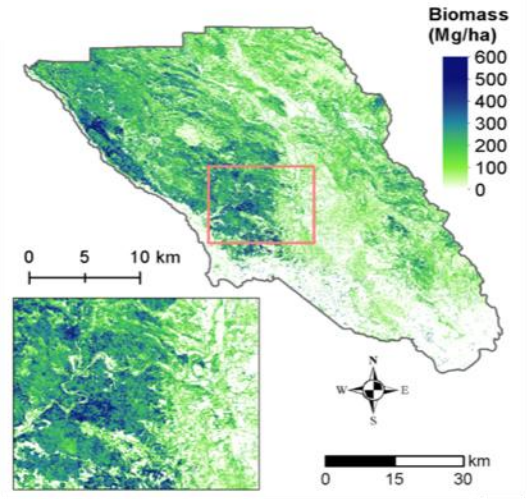
1. TLS and Field Data for plot biomass estimates

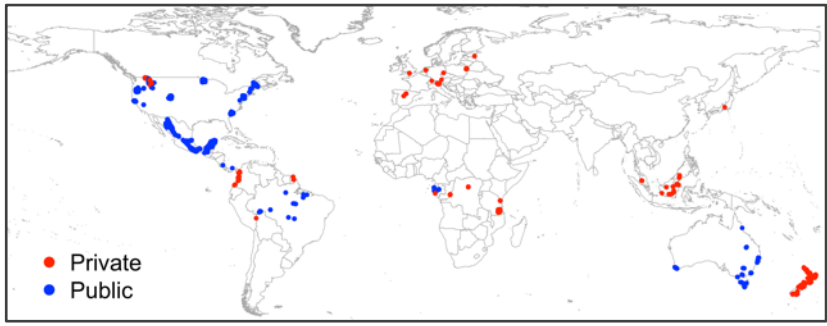




2. Calibrate Airborne lidar with *in situ* data

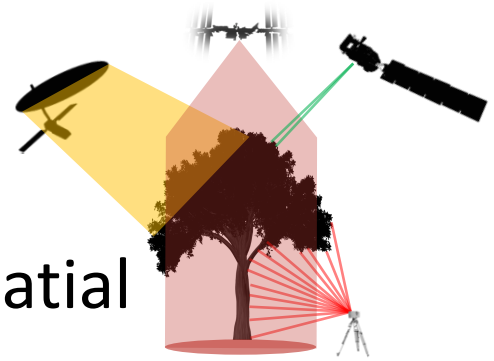
3. Generate local biomass maps at desired (spaceborne product) resolution





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

Timeline	Activities
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

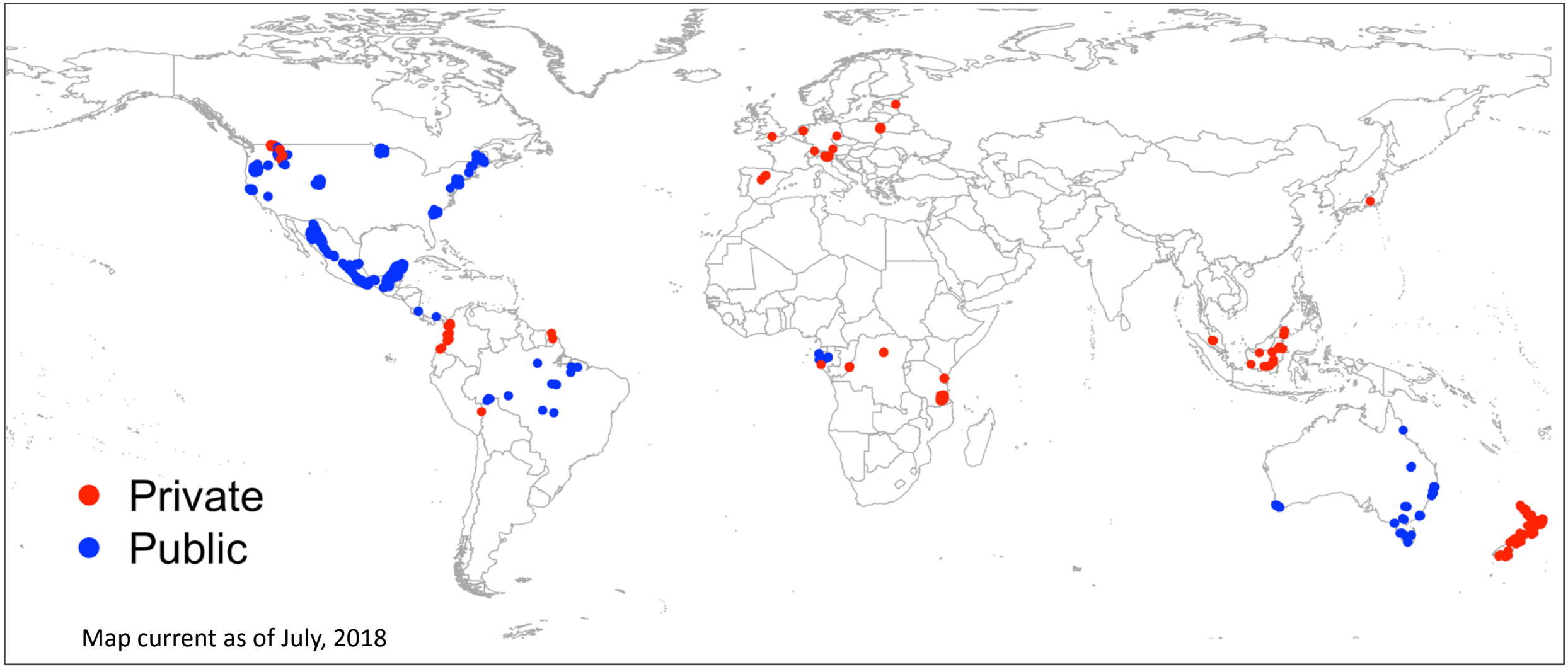
Toward Protocol Implementation

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

Multi-Mission Biomass Cal/Val Group

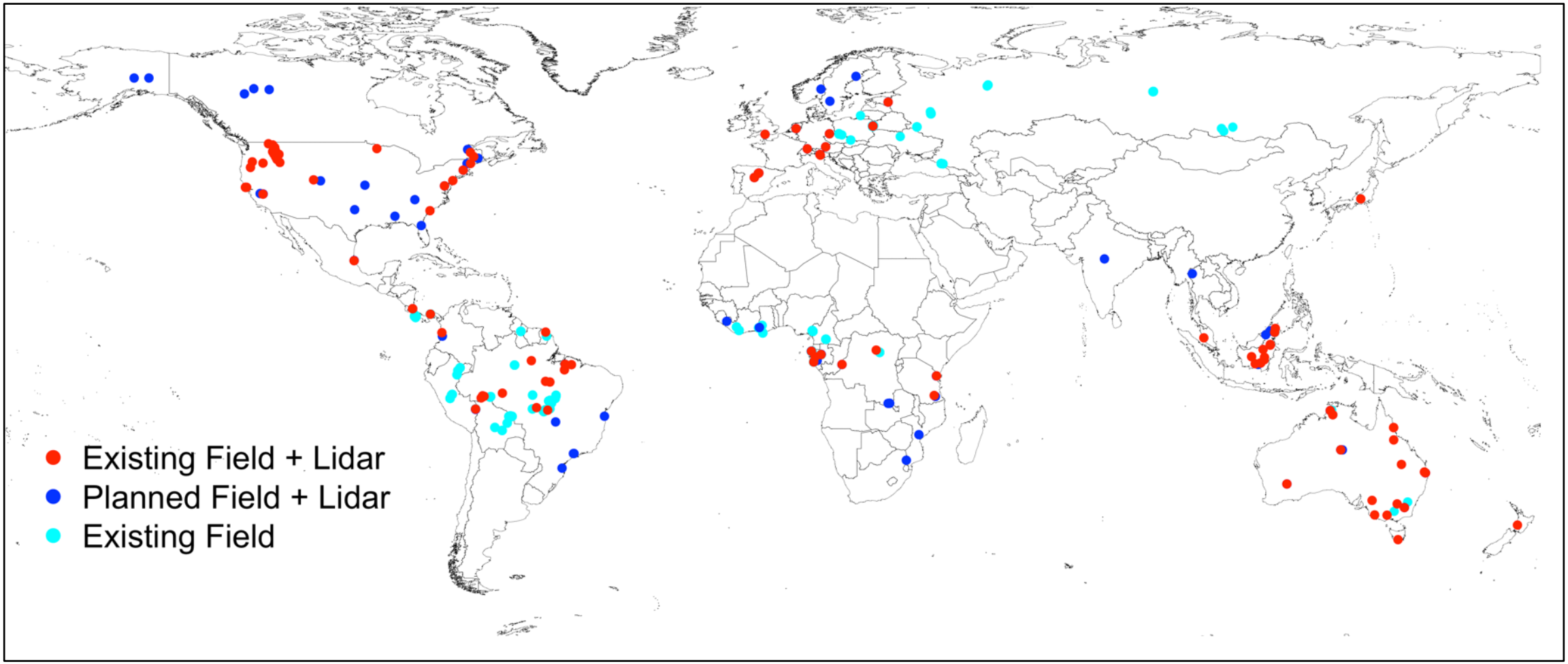
Monthly telecons between members of NASA GEDI, ICESat-2, ESA BIOMASS and NASA/ISRO NISAR team, as well as representatives from plot networks (ForestPlots, ForestGEO, FOS)

- 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

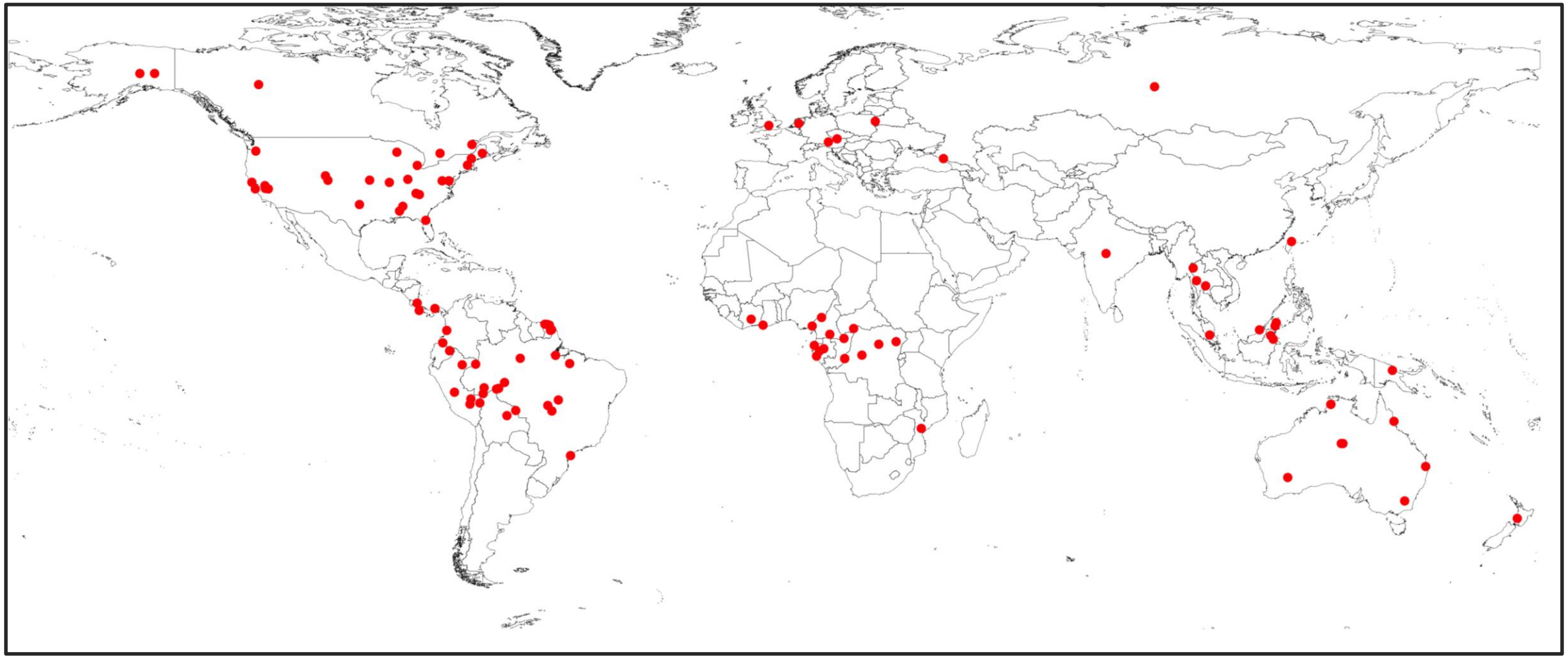
- **NISAR:**
  - Bruce Chapman
  - Paul Siquiera
  - Victoria Meyer
  - Naiara Pinto
  - Sassan Saatchi
  - Paul Rosen
- **GEDI:**
  - Ralph Dubayah
  - Laura Duncanson
  - Michelle Hofton
  - Lola Fatoyinbo
  - John Armston
  - David Minor
  - Jim Kellner
- **BIOMASS:**
  - Klaus Scipal
  - Shaun Quegan
  - Jerome Chave
  - Nicolas Labriere
  - Clement Albinet
- **Plot Networks:**
  - Stuart Davies
  - Oliver Phillips
  - Jerome Chave
- **MAAP:**
  - Marco Lavalle
  - Clement Albinet
  - Amanda Whitehurst
  - Laura Duncanson
- **Other:**
  - Mike Falkowski (NASA HQ)
  - Richard Lucas (CCI Biomass)
  - Amy Neuenschwander (ICESat-2)
  - Mat Disney (UCL, CEOS LPV)

Data Sharing and Coordinated Data Collection



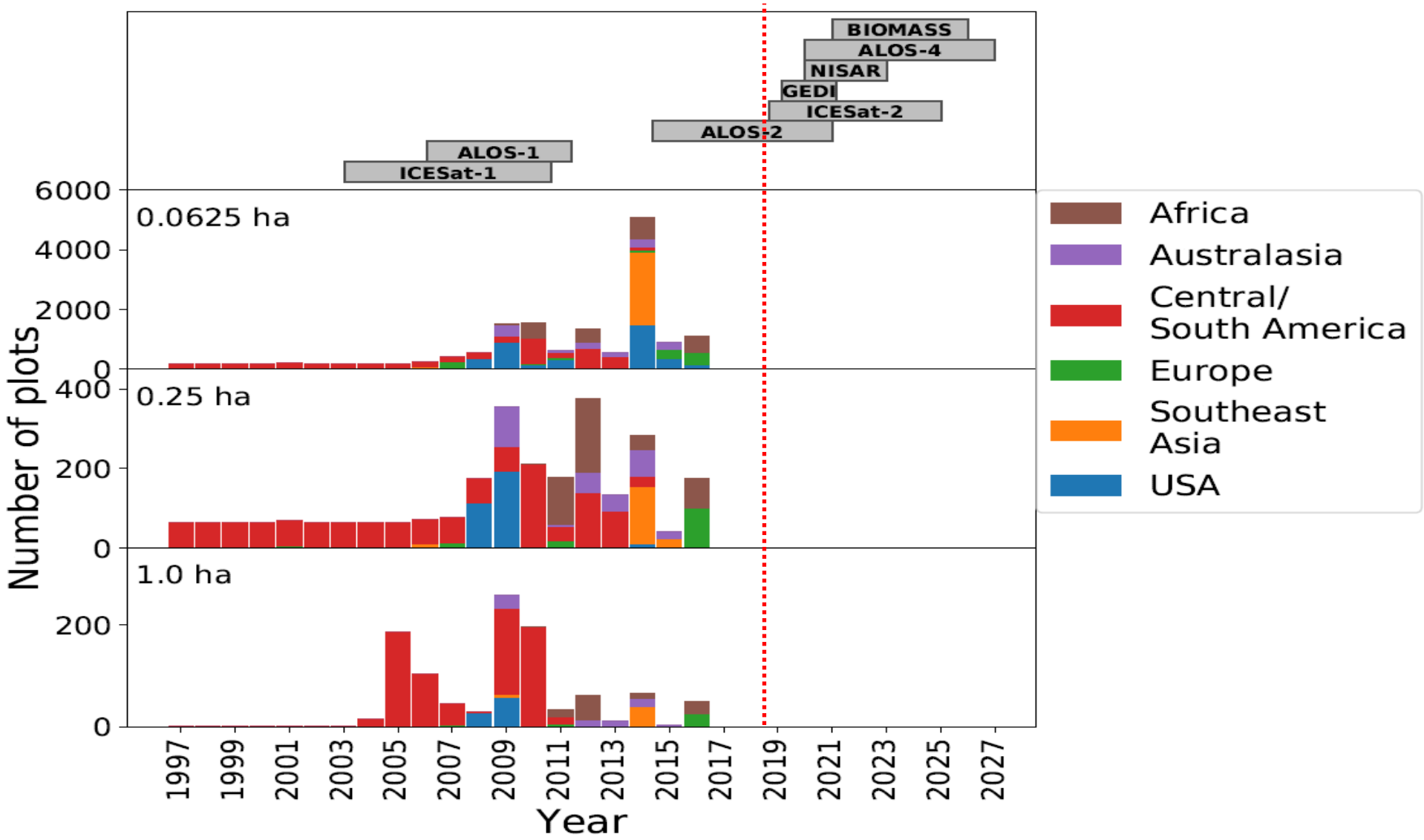
GEDI, ICESat-2, NISAR, and ESA BIOMASS teams are working on coordinated cal/val

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

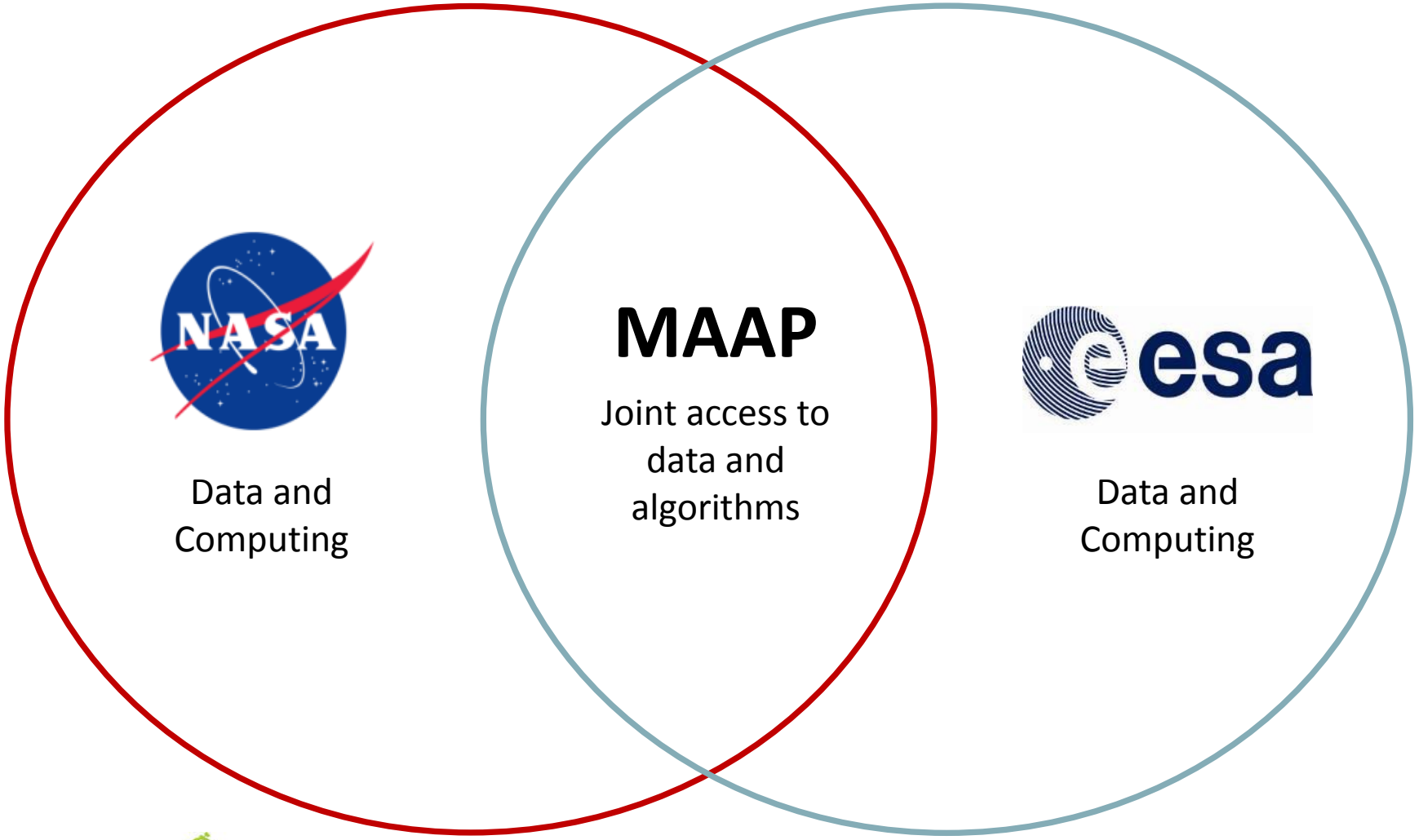
- Multi-mission team is collating a list of known disturbed forest plots for this pilot study, comparing results to landsat-based disturbance monitoring

Planet data Explored for Automatic Detection of Disturbance in Reference Plots

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

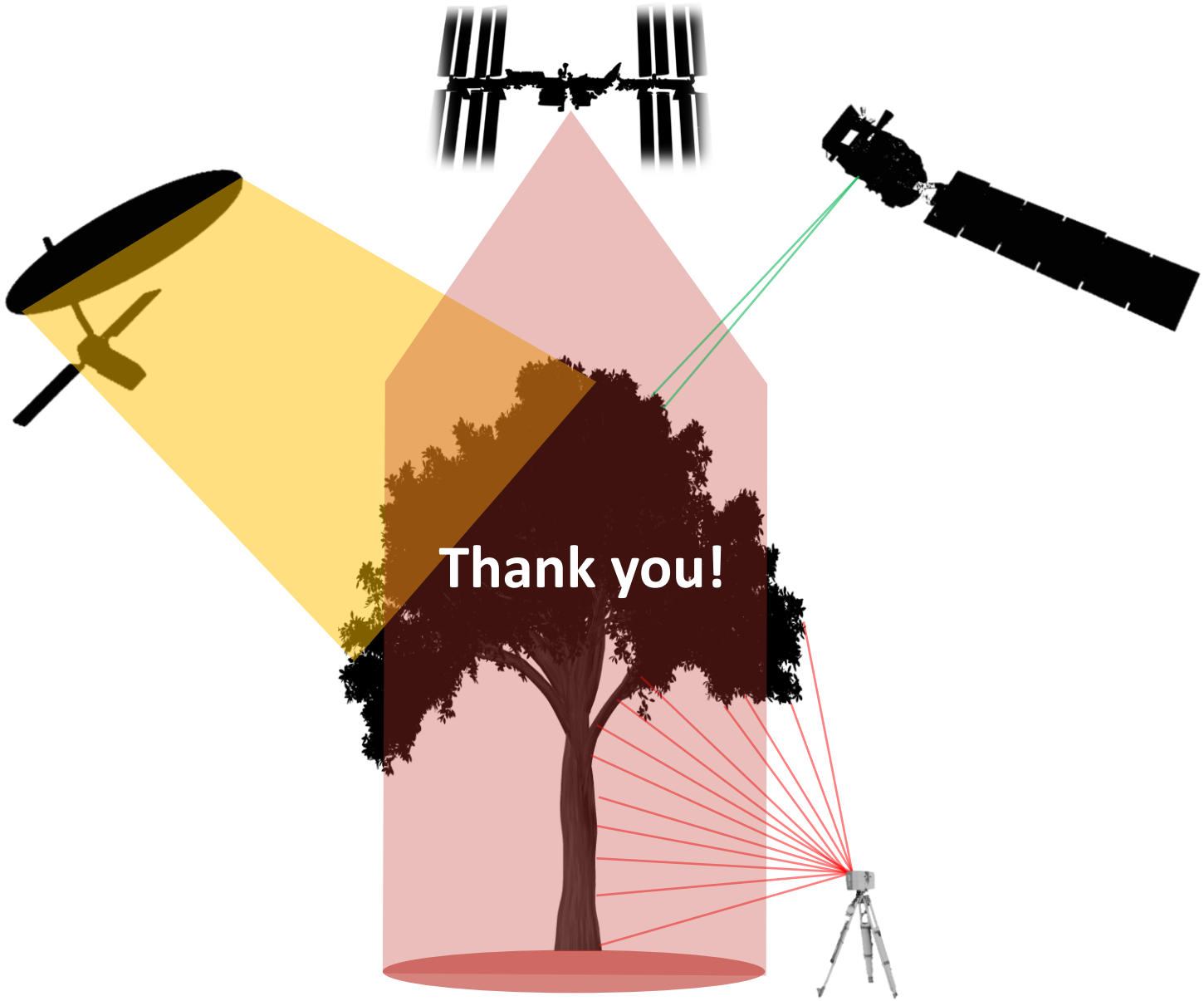
Potential for Validation Portal Development Via the Multi-mission Analysis and Algorithm Platform



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

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!