



Applied Remote Sensing Training (ARSET) Program

Estimating Biomass and Change with GEDI and the OBIWAN API

Homework Questions

Question 1

GEDI's main observable is a waveform of returning laser energy. The GEDI L4A Footprint Biomass product assigns an above-ground biomass density (AGBD in megagrams per hectare) to each waveform. Where does that biomass value come from?

Answers: (bold correct)

- a. The same AGBD value is assigned to all footprints in a given ecosystem.
- b. A linear model is fitted between properties of waveforms simulated from airborne lidar and coincident AGBD field measurements from across the world.**
- c. Generative AI ingests the waveforms and simulates all tree crowns and an aggregate AGBD estimate.
- d. Lidar penetrates the bark and directly measures the mass of all trees in the footprint.

Feedback:

GEDI L4A biomass estimates are based on extensive field measurements of aboveground biomass paired with spatially coincident airborne lidar observations. Statistical linear models are developed from these relationships and then applied to GEDI waveforms to estimate AGBD at each footprint.

Linear models are especially useful because they allow model uncertainty to be propagated into larger-scale sample-based estimates, such as the 1 km biomass estimates in the GEDI L4B product.

The other answers are incorrect: GEDI does not assign a single biomass value to entire ecosystems, does not use generative AI to reconstruct forests, and laser light does not penetrate wood to directly measure tree mass.

Question 2

Generalized Hierarchical Model-Based (GHMB) estimation is a method that uses ancillary wall-to-wall imagery to estimate biomass for all parts of an area of interest instead of just the areas where GEDI shots have been collected. In which case is GHMB used in the L4B product to estimate AGBD instead of the algorithm that considers only the footprint-based L4A AGBD predictions?

Answers:

- a. **For 1 km cells without enough GEDI footprints to support a sample-based estimate.**
- b. When all waveforms were collected at nighttime.
- c. Only when completely cloud-free Landsat imagery is available.
- d. The estimate in the L4B product is always the average of the two approaches.

Feedback:

The L4B product uses two different estimation approaches depending on the density of available GEDI waveforms within a 1 km grid cell. When there are enough GEDI footprints to support a reliable estimate, the product uses the waveform-only (hybrid model-based) approach because it is simpler and relies directly on lidar observations, which are generally more strongly related to AGBD than optical imagery.

However, when there are too few GEDI footprints within a cell to support estimation, the Generalized Hierarchical Model-Based (GHMB) method is used. GHMB incorporates ancillary wall-to-wall imagery to extend biomass estimates across areas lacking sufficient GEDI sampling.

Question 3

Choose the only false statement about OBIWAN's use of bootstrapping.

Answers:

- a. Bootstrapping can be performed ahead of time, saving time at the point of query.
- b. Bootstrapping generally returns variances similar to those produced by closed-form equations that are based on similar assumptions.
- c. Bootstrapping is intuitive.
- d. **Bootstrapping always returns tight confidence intervals.**

Feedback:

Bootstrapping does not guarantee tight confidence intervals. If the underlying data are highly variable or the predictive model is weak, bootstrap estimates can produce large variances and wide confidence intervals, just like analytical variance equations.

The other choices are valid reasons for using bootstrapping in OBIWAN. Bootstrapping is flexible, intuitive, and can approximate uncertainty estimates that are similar to those produced by closed-form statistical methods while also allowing many calculations to be precomputed.

Question 4

Why is a large number of bootstraps preferable to a small number?

Answers:

- a. Variances are in square units, and the number of bootstraps must therefore be a perfect square.
- b. There may be error scenarios important for variance calculation that are relatively rare and require (on average) a number of bootstraps to be represented.**
- c. A larger number of bootstraps reduces the computation needed to calculate uncertainty.

Feedback:

A larger number of bootstraps is preferred because variance estimates can be unstable when too few bootstrap samples are used. Some sources of error may occur relatively rarely, so many bootstrap iterations are needed to ensure those scenarios are adequately represented in the uncertainty estimate. As the number of bootstraps increases, the variance estimate generally becomes more stable and reliable.

The other answers are incorrect: variances do not require the number of bootstraps to be a perfect square, and increasing the number of bootstraps increases computational effort rather than reducing it.

Question 5

Which two of the following approaches are ways that OBIWAN supports the evaluation of additionality, that is, to assess whether a management strategy produced a measurable effect of a

particular management strategy beyond what would have happened otherwise? (Select all that apply.)

Answers:

- a. Comparing change monitored on an area of interest to the average change on all possible polygons of the same size across the continent
- b. Comparing change monitored on an area of interest to the change estimated from NASA/ISRO's NISAR radar satellite
- c. Comparing change monitored in an area of interest after a management strategy was implemented to the change monitored in the same area before implementation**
- d. Comparing change monitored in an area of interest to a carefully selected “counterfactual” area where the management strategy was not implemented**

Feedback:

Both c and d are correct.

The OBIWAN notebook demonstrates two approaches for evaluating additionality:

Before-and-After Comparison — Comparing changes in the same area before and after a management intervention was implemented.

Counterfactual Comparison — Comparing changes in the managed area to a similar area where the intervention did not occur.

NISAR data are not yet broadly available and are not currently used within OBIWAN, so option b is incorrect.

Question 6

Which of the following are valid reasons to apply calibration using either independent inventory data or GEDI L4A AGBD predictions that were not used to train OBIWAN's Landsat-based biomass model?

Answers:

- a. Calibration with ground inventory data can align GEDI biomass models with locally used definitions and field measurement protocols.

- b. Calibration with ground data can help relate GEDI biomass models to other forest variables, such as stand volume, that are correlated with biomass.
- c. Calibration can be applied after bootstrapping, so the computationally intensive bootstrap process does not need to be repeated and results can be generated quickly.
- d. All of the above.**

Feedback:

Calibration is primarily used to reduce systematic bias and improve consistency between biomass estimates and independent data sources. It can help align GEDI-based estimates with local inventory methods, connect biomass estimates to related forest variables such as stand volume, and be applied efficiently after the bootstrap process without rerunning computationally intensive uncertainty calculations.

It is important to note, however, that calibration does not necessarily reduce uncertainty or narrow confidence intervals. In some cases, calibration can increase variability among bootstrap estimates.

Question 7

Which of the following is a true statement about validation of biomass change with USDA Forest Service inventory data?

Answers:

- a. Calibration with independent GEDI L4A AGBD values usually produces better results than calibrating with change measurements from revisited field plots.
- b. Without calibration, changes are almost always over-predicted.
- c. The estimated confidence interval is a good measure of overall uncertainty in most cases.
- d. In some cases, certain types of biomass change (for example, losses and small gains) are estimated accurately, whereas others (e.g., large gains) are not.**

Feedback:

In some cases, large gains are difficult to differentiate from medium gains, suggesting an incentive to keep the time period of interest relatively short. In many cases, especially those without calibration, OBIWAN produces estimates that are very precise (small confidence intervals) but not very accurate (far from the 1:1 line, indicating substantial bias).

Question 8

Which of the following can be a disadvantage of pre-storing global mapped bootstraps on Google Cloud in a way that can be easily accessed through a public API:

Answers:

- a. **Everyone can see the results of every query.**
- b. Bootstrapping needs to be done only once.
- c. Queries return results rapidly.
- d. It is easy to standardize reporting processes across countries or across participants in a particular market.

Feedback:

Individual users can elect to store results with whatever level of security they choose, supporting both proprietary applications and transparent forums for reporting additionality. The other choices are wonderful reasons for OBIWAN's open API approach.