Global Ecosystem Demography Model (ED-global v1.0): Development, Calibration and Evaluation for NASA's Global Ecosystem Dynamics Investigation (GEDI)

Lei Ma[1], George Hurtt[2], Lesley Ott[3], Ritvik Sahajpal[1], Justin Fisk[1], Steve Flanagan[4], Benjamin Poulter[3], Shunlin Liang[1], Joe Sullivan[1], and Ralph Dubayah[1]

[1]University of Maryland at College Park
[2]University of Maryland,Princeton University
[3]NASA Goddard Space Flight Center Greenbelt
[4]Tall Timbers Research Station and Land Conservancy

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Abstract

Climate mitigation and forest management require accurate information on carbon stocks, fluxes, and potential future sequestration potential. Previous large-scale estimates have substantial uncertainties arising from lack of data, heterogeneity of forest structure, and modeling limitations. However, recent local-to-regional studies suggest that combination of lidar-derived canopy height with an advanced 3-D ecosystem model that explicitly tracks vegetation height (i.e. Ecosystem Demography, ED) can reduce uncertainties and provide mapped estimates of these quantities at high-spatial resolution over policy relevant domains. Extending this approach to the global scale requires both a source of global lidar data height data and a global height structured ecosystem model. The NASA GEDI mission provides precise measurements of forest canopy height and vertical structure with great potential for global carbon cycle modelling. Here we present recent development and calibration of ED-global (v1.0) and its evaluation simulations against heterogeneous sources of satellite observations and field measurements. ED-global estimates of vegetation carbon stocks and fluxes, vegetation distribution and structure will be examined across various temporal and spatial scales from seasonal to inter-annual and also from grid cell to biome. The developed ED-global will serve as base model of NASA's GEDI mission to answer the key science questions: What is the carbon balance of Earth's forests? And how will the land surface mitigate atmospheric CO2 in the future?

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[1]Univ. of Maryland, College Park, [2]NASA GSFC, [3]Applied Geosolutions, New Hampshire, [4]Tall Timbers Research Station, Florida

Ecosystem Demography (ED) Model

- Individual-based terrestrial biosphere model characterizing fine-scale plant competition for light, water and nutrient.
- Use Size- and Age-Structured (SAS) partial differential equation system to capture vertical and horizontal heterogeneity in light, water and nutrient availability.
- Closely approximates ensemble behavior of stochastic gap models but is more efficient for large-scale studies of ecosystem dynamics in response to climate change, varying CO_2, land use change and natural disturbance.

Motivation to Develop ED-global

- Global initialization and prediction of carbon sequestration with GEDI data.
- Impacts of land use changes on forest succession and structure.
- Demographic ecosystem response to climate change.

Methods

I. Leverage regional versions of ED to global version.

II. Spin-up global model to current ecosystem state through two stages.

III. Compare estimates of GPP, NBP, LAI, AGB, etc. to a benchmarking package.

IV. Refine and re-parameterize submodules.

Two-stage spin-up:

- Equilibrium simulation: spin-up 1000 years from bare ground to equilibrium state in carbon pools.
- Transient simulation: continue running for 1166 years (850-2016).

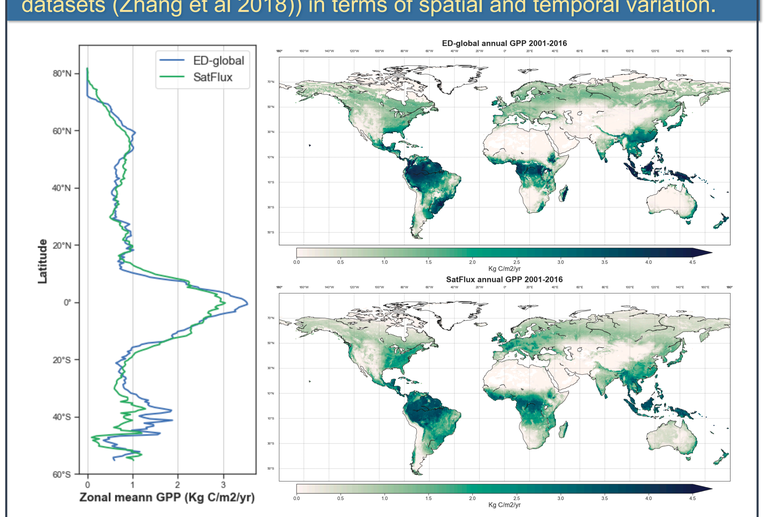
Forcings:

Meteorology from NASA MERRA2 reanalysis; land use change from LUH2; burned area from GFED4; varying CO_2 from NOAA.

Features of ED-global v1.0

- ❑ Detailed characterization of vegetation demography.
- ❑ Explicit height of plants, potential for direct connection to LiDAR data.
- ❑ Characterization of LULCC impacts (e.g., disturbance).
- ❑ Plant migration.
- ❑ Operates at both local and global scales with flexible spatial resolution.
- ❑ Climate variability (e.g., temperature, precipitation and CO_2).
- ❑ Evaluated with a full benchmarking package.

GPP Evaluation: ED-global GPP was compared to satellite observations (e.g., SatFlux (Joiner et al 2018) and Sun-Induced Fluorescence (SIF) datasets (Zhang et al 2018)) in terms of spatial and temporal variation.



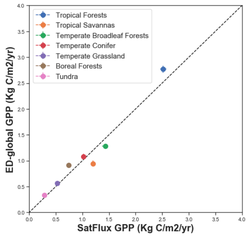
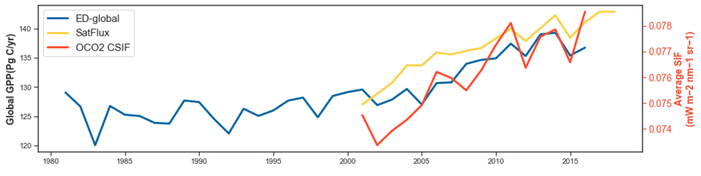


Figure 1 (top). Spatial pattern comparison of 2001-2016 average GPP between ED-global and SatFlux.

Figure 2 (left). Biome-average 2001-2016 GPP comparison between ED-global and SatFlux.

Figure 3 (bottom). Inter-annual variation in global GPP from ED-global and SatFlux and averaged SIF.



LAI Evaluation: satellite LAI product (GEOV2) was used to examine if ED-global could capture temporal trend and variation in LAI.

Vertical LAI Evaluation: examine if ED-global reproduce observed LAI profile

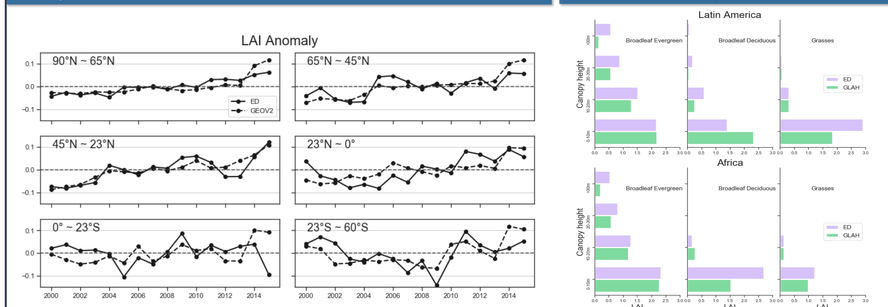


Figure 4 (left). Annual LAI anomaly of ED-global and GEOV2 for different latitudinal bands.

Figure 5 (right). LAI profile comparison between ED-global and LiDAR observations of ICESat-1 (Hao et al 2014) across three PFTs at tropics.

NBP Evaluation: TRENDY DGVMs and atmospheric inversions were used to examine if ED-global could reproduce the mean, trend and variation of NBP

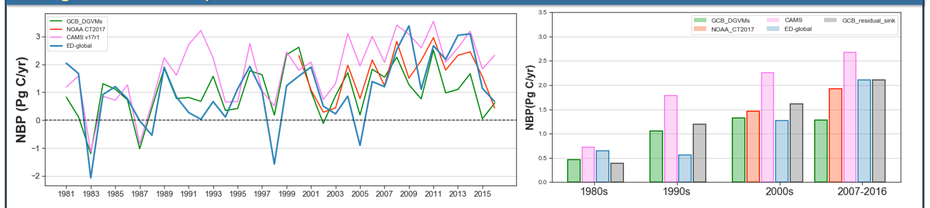


Figure 6 (left). Global NBP time series from ED-global, atmospheric inversions (NOAA CT2017 and CAMS v17r1) and ensemble mean of TRENDY DGVMs.

Figure 7 (right). Comparison of decadal mean of global NBP from ED-global and other approaches.

Biomass Evaluation: spatial pattern of AGB from ED-global and GEOCARBON product.

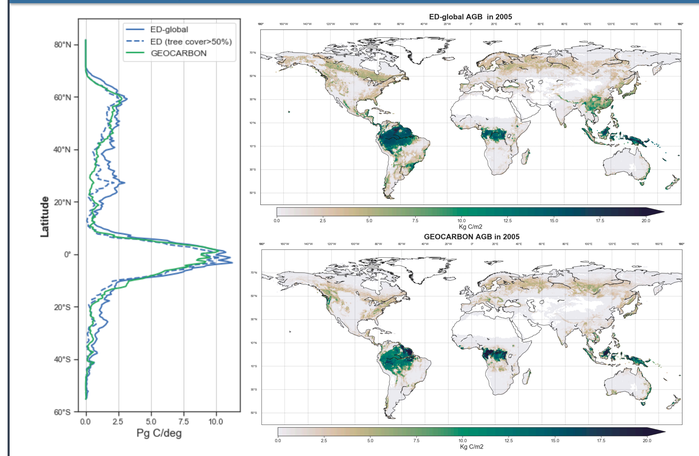


Figure 8. AGB in 2005 from ED-global estimates and satellite-based product from the GEOCARBON project. GEOCARBON AGB only covers forested area.

Next Steps

- ❖ Global initialization of ED-global with GEDI collected canopy height datasets.
- ❖ Continued refinement of ED-global.
- ❖ Incorporate other remote sensing data (e.g., forest change, disturbance)
- ❖ Local-global applications: CMS, GEDI and IDS, etc.

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E-mail: lma6@umd.edu