Using CLM(ED) as a basis for representing carbon cycling dynamics in tropical forests

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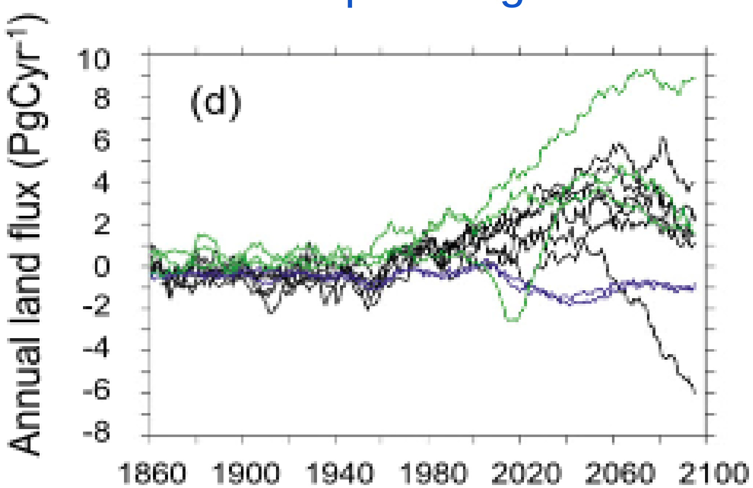
- Old-growth tropical forests are responsible for a large portion of the terrestrial carbon sink.
- In order to improve the quantification of the carbon cycle there is a strong emphasis on incorporating **improved vegetation structure and competition** in land-surface modeling.

Uncertainties in land carbon flux from tropical regions



Friedlingstein et al. 2014, Nature Geoscience, (CMIP5 analysis)

Climate change pushing **tropical** ecosystems into **novel regimes**

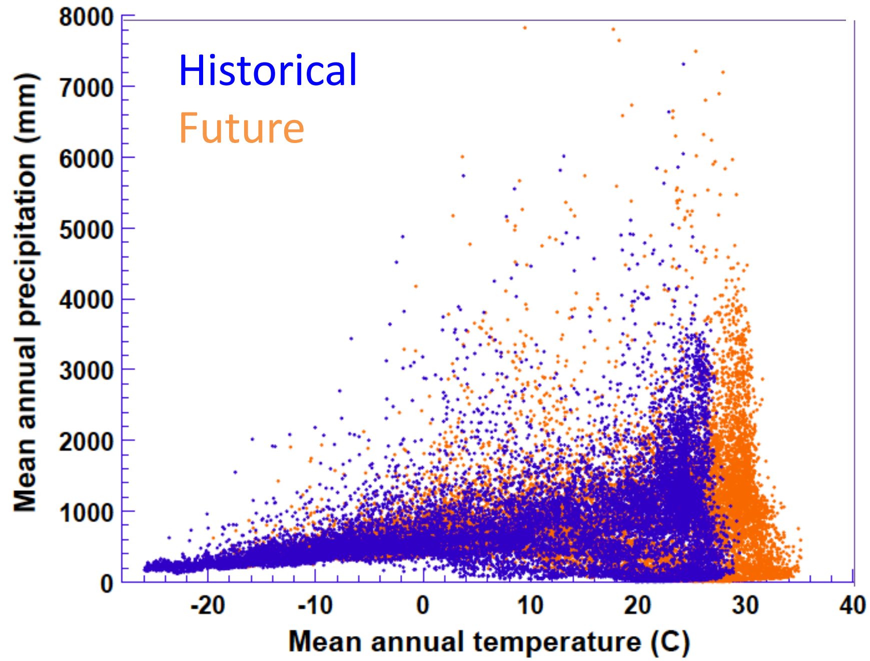


Figure courtesy of Charlie Koven

What are the "pros" to demographic and dynamic vegetation modeling?

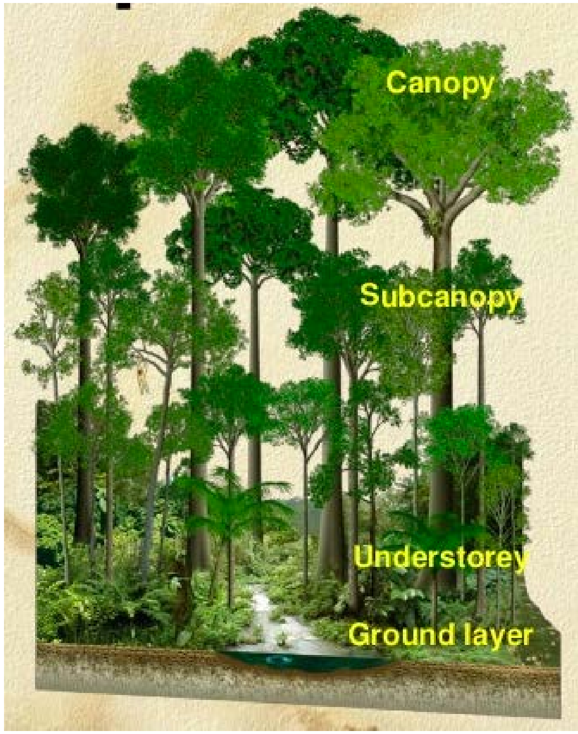
- Includes disturbances, bioclimatic constraints
- Competition for light, water, nutrients, climate dependent
- Dynamic mortality and establishment

Complex tropical forest structure and strata. Varying size and age classes

- CLM prior to Ecosystem Demography Model (ED)

  CLM4.5 BGC (lack of demographics)

  Vegetation treated as a "big leaf model"

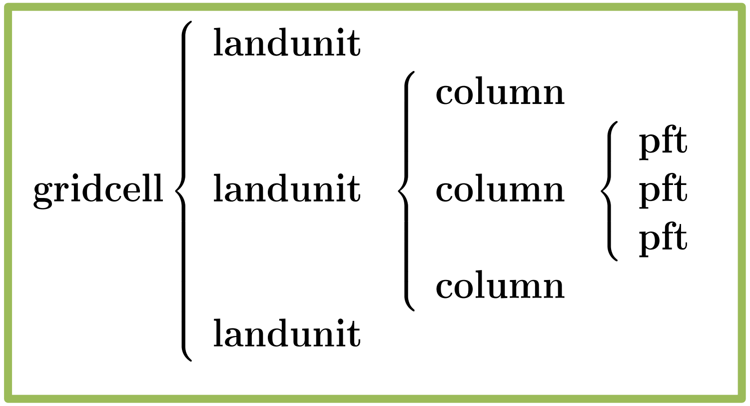


Objectives:

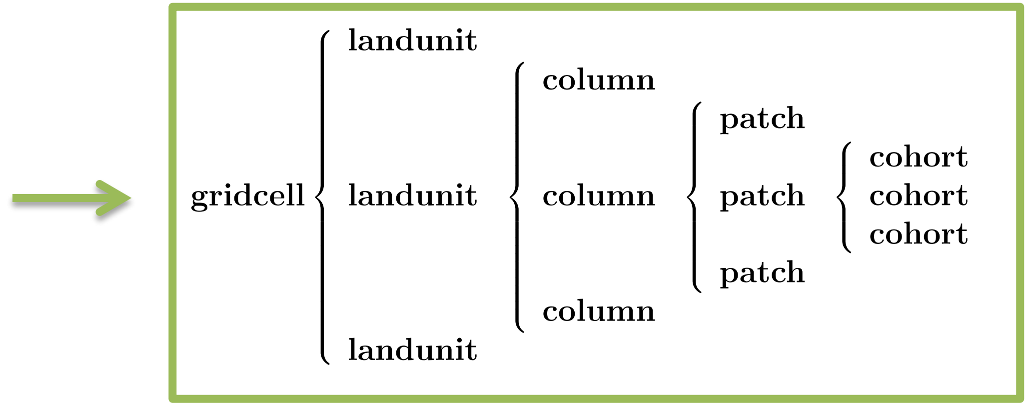
- Testing, diagnosing, and fine-tuning the newly coupled CLM(ED).
- Evaluate plant growth, forest succession, carbon fluxes in CLM(ED) and compare to field data, CLM 4.5, and ED2

CLM(ED)

- Land surface divided into common-disturbance-history "**patches**". Classified as age since disturbance in years.
- Patches are divided into plant functional types (PFTs) and then height classes, called "**cohorts**".
- Each cohort is a group of similar plant types.
- Cohort based model with **competition and co-existence**, allowing for successional stages, size structure, competition between PFTs (Moorcroft et al. 2001).
- **Big caveat – CLM(ED) still uncalibrated, still in testing phase against data**



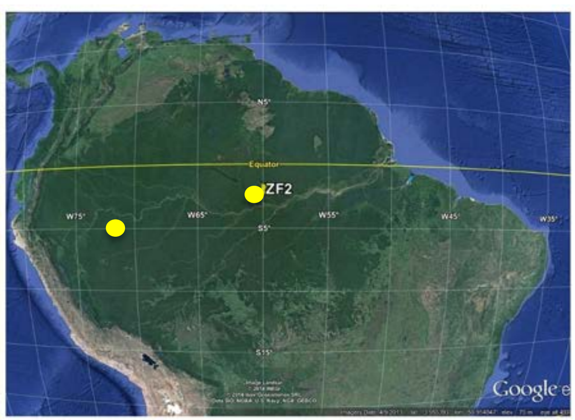
CLM Hierarchy



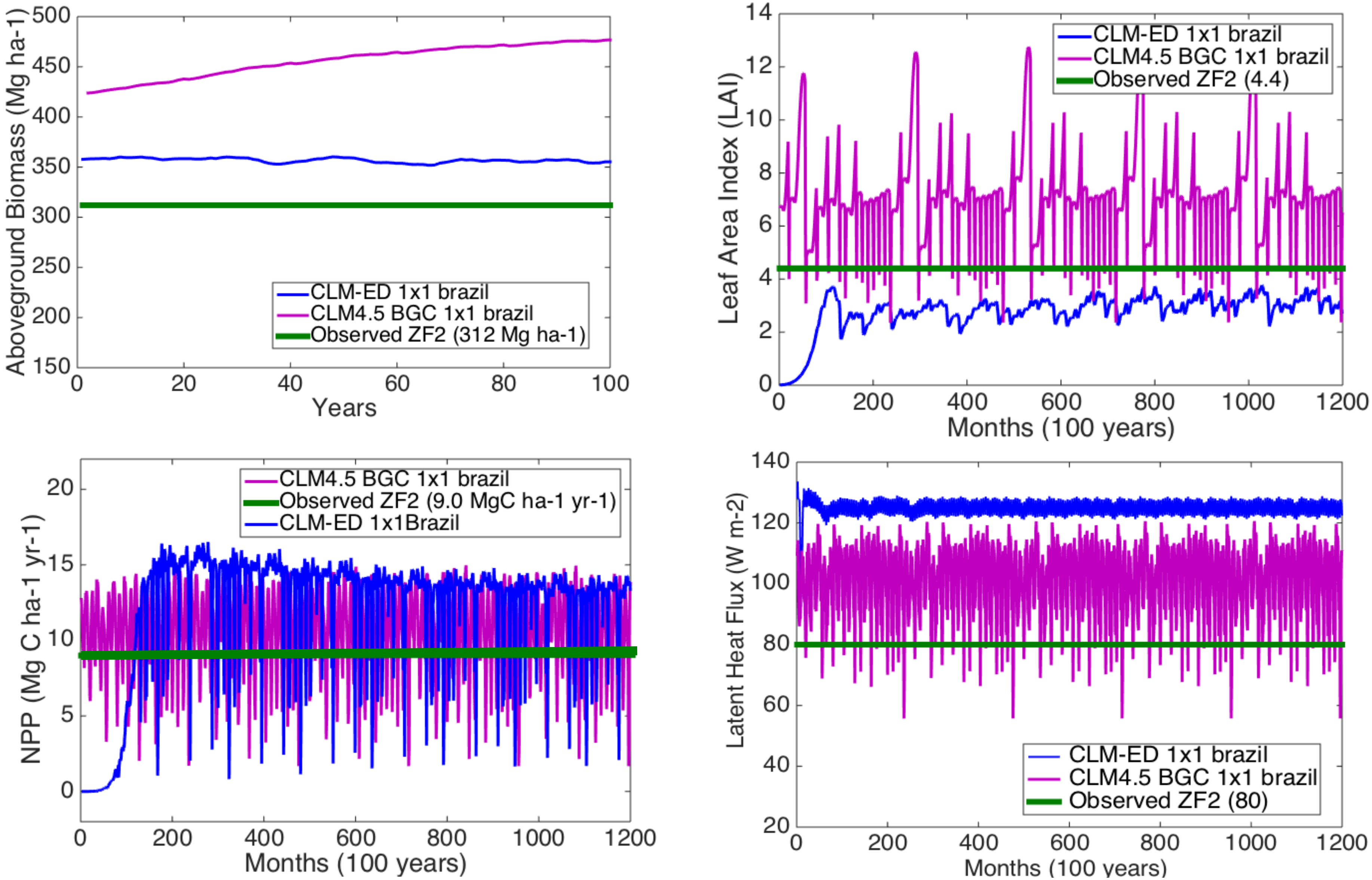
CLM(ED) Hierarchy

Central Amazon field site ("ZF2")

- Observational Field data = Central Amazon, old-growth, field inventory began in 1996.
  - ZF2 site, 100 miles north of Manaus
  - Two 5-ha transects
  - Model forced with meteorological tower data
  - Comparing to single point CLM(ED)
- 2nd site: Northwest Amazon, Iquitos Peru
- Developing pan-tropical test-bed with suite of CLM(ED) single point runs

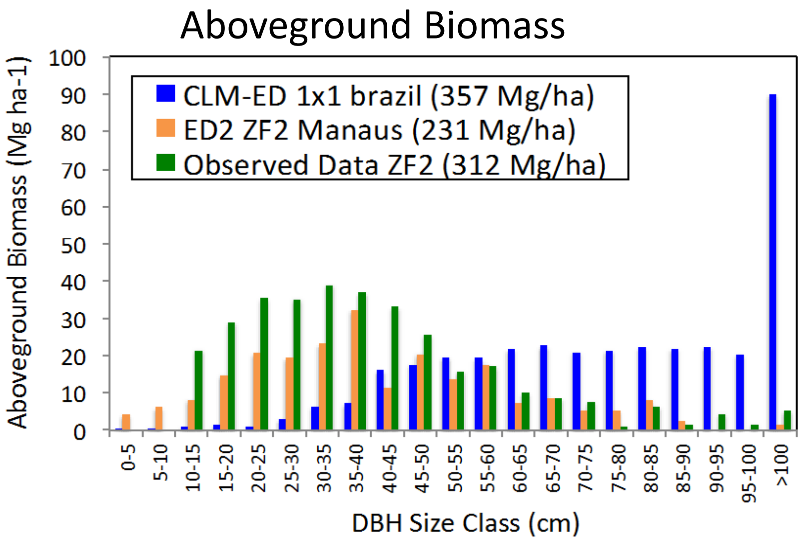


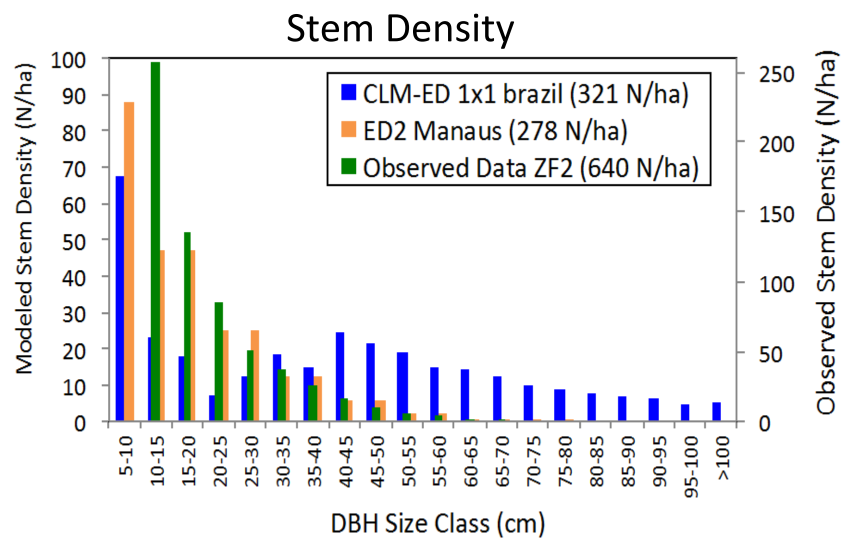
Tropical Forest CLM(ED) vs. CLM4.5 vs. Observed

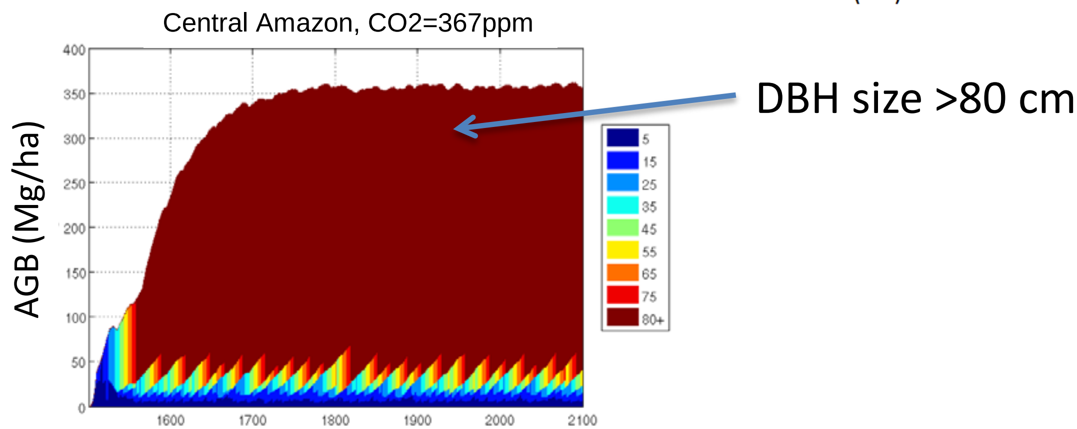


CLM(ED) vs. ED2 vs. Observed

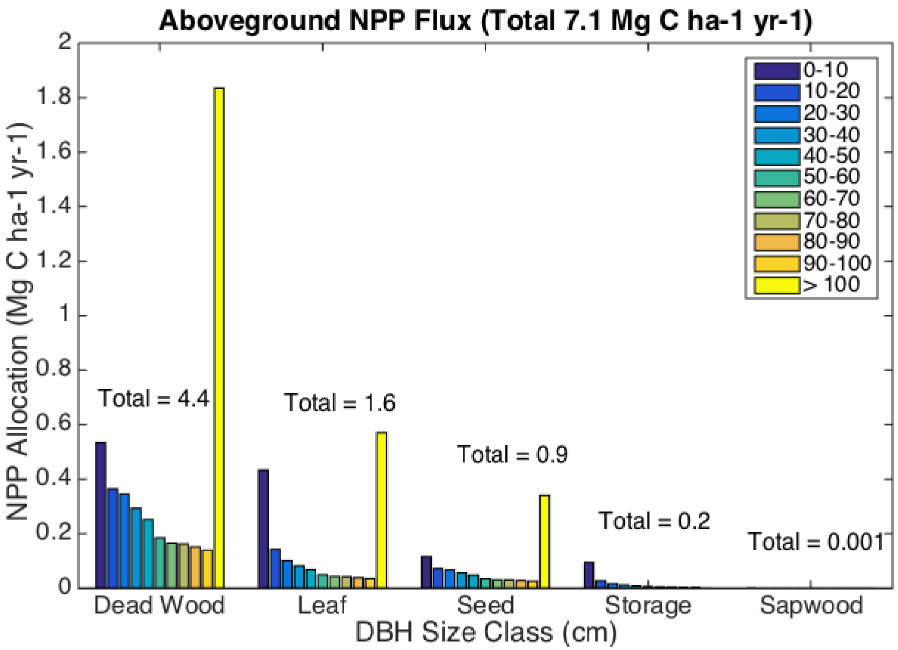
- Total AGB close to observed (357 vs. 312 Mg/ha)
- Bias towards very high biomass in largest stem size class

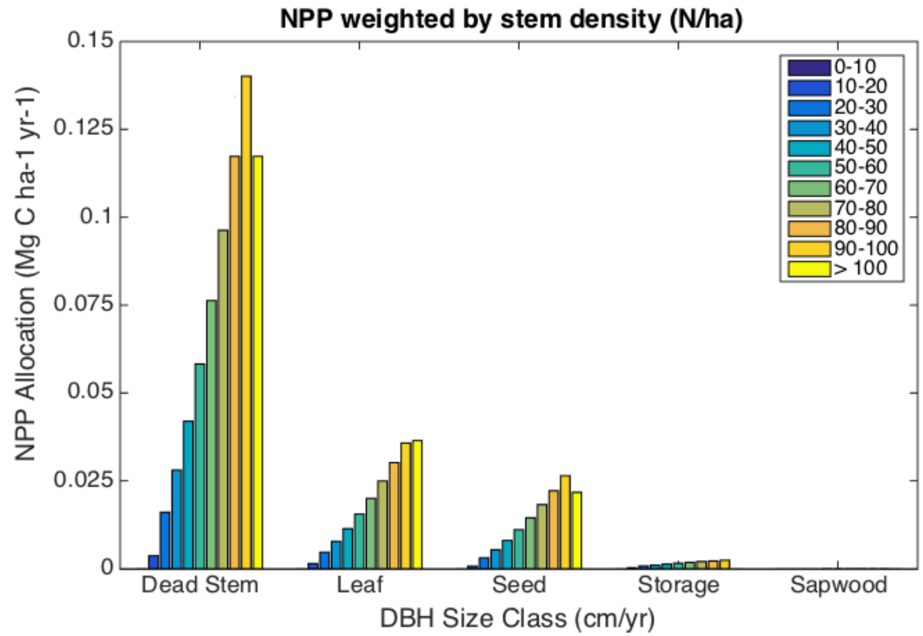






CLM(ED) NPP Flux

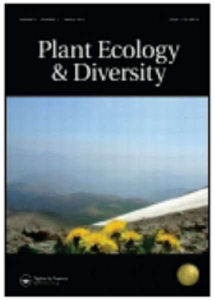




NPP flux into >100 cm size class due to high stem density in >100 cm

Realistic NPP flux pattern when weighted by stem density

Mg C ha^{-1} yr^{-1}	CLM(ED)	Chambers et al. 2001
Dead Wood	4.4	3.2
Leaf	1.6	3.3
Seed	0.9	NA
Storage	0.2	NA
Sapwood	0.001	NA
Total	7.1	6.5



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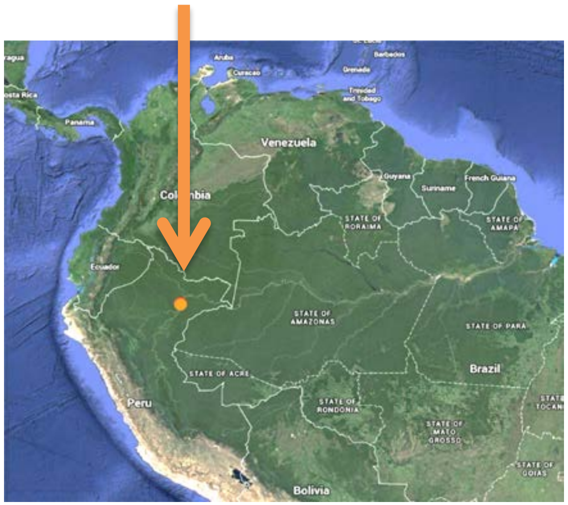
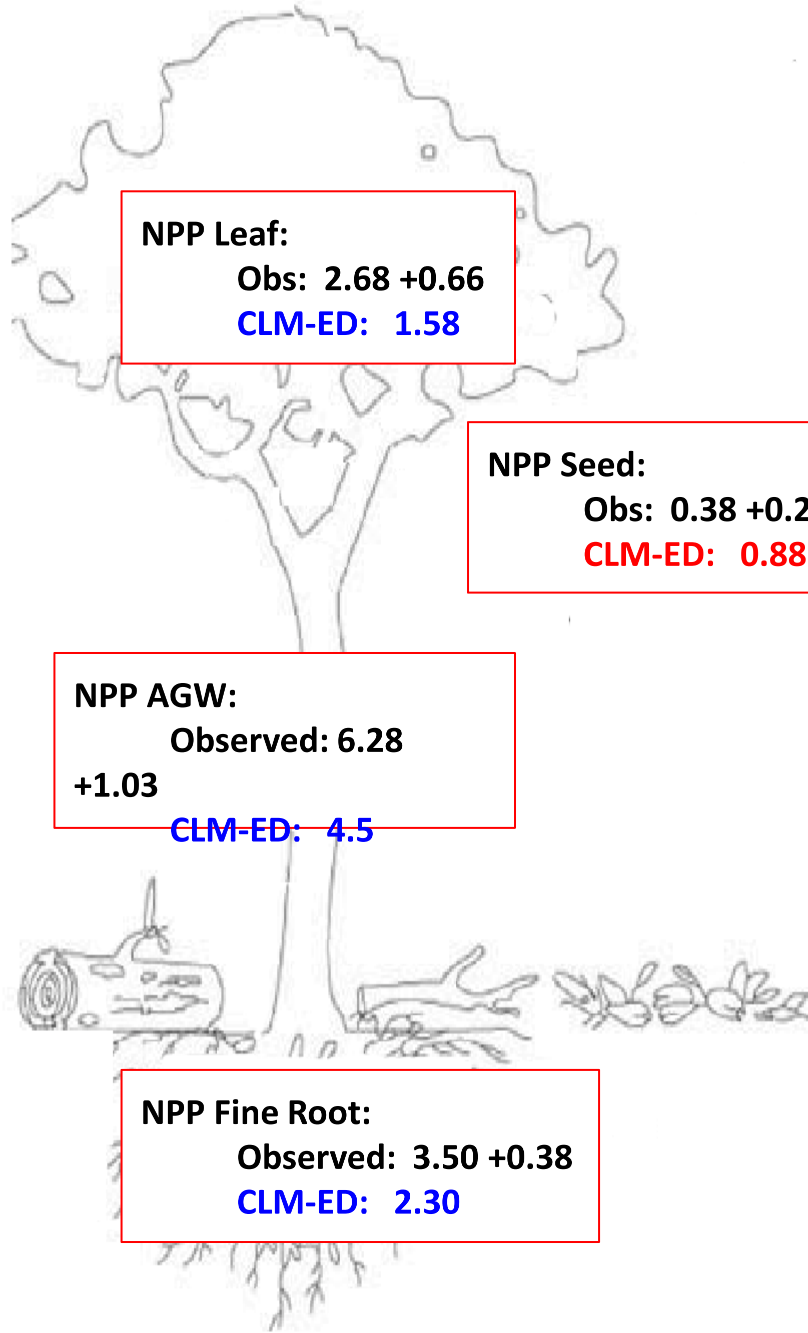




NPP Leaf:
Obs: 2.68 +0.66
CLM-ED: 1.58

NPP Seed:
Obs: 0.38 +0.29
CLM-ED: 0.88

NPP AGW:
Observed: 6.28 +1.03
CLM-ED: 4.5

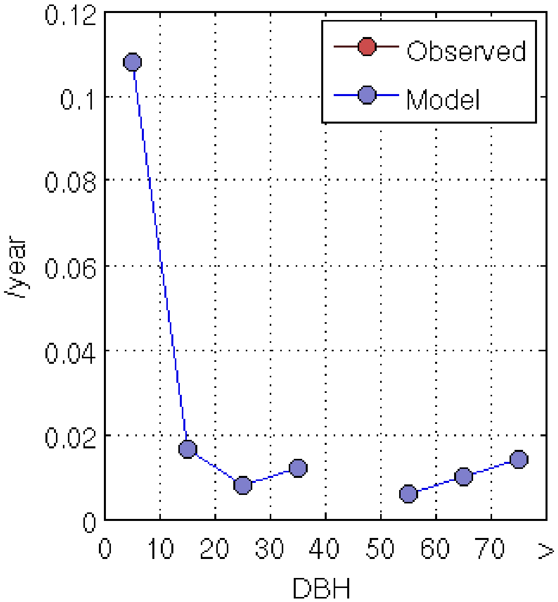
NPP Fine Root:
Observed: 3.50 +0.38
CLM-ED: 2.30

Number Density:
Obs: 576 /ha
CLM-ED: 172 /ha

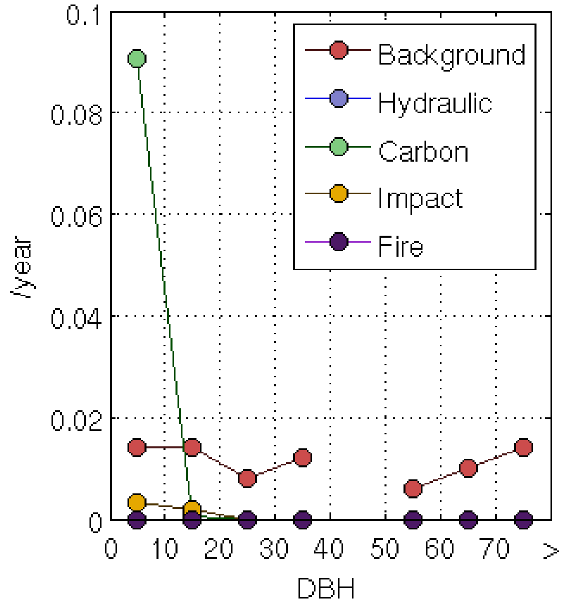
NPP: Obs: 14.14 +.99 [MgC/ha/yr]
CLM-ED: 12.56 [MgC/ha/yr]

GPP: Obs: 39.05 +4.6
CLM-ED: 24.25

Mortality Rate

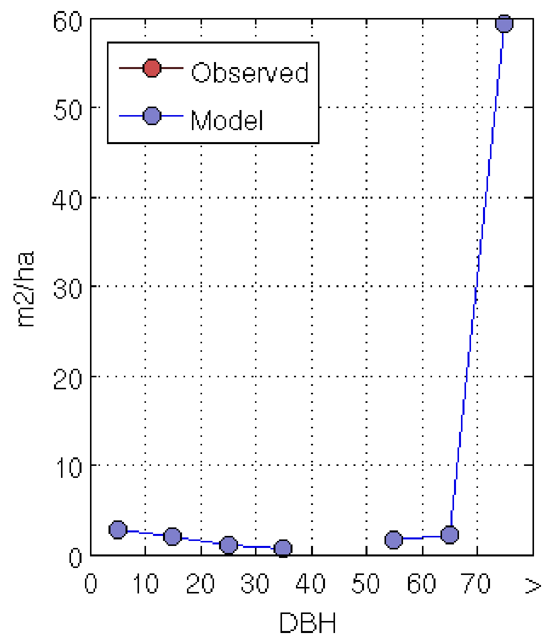


Mortality Partitions

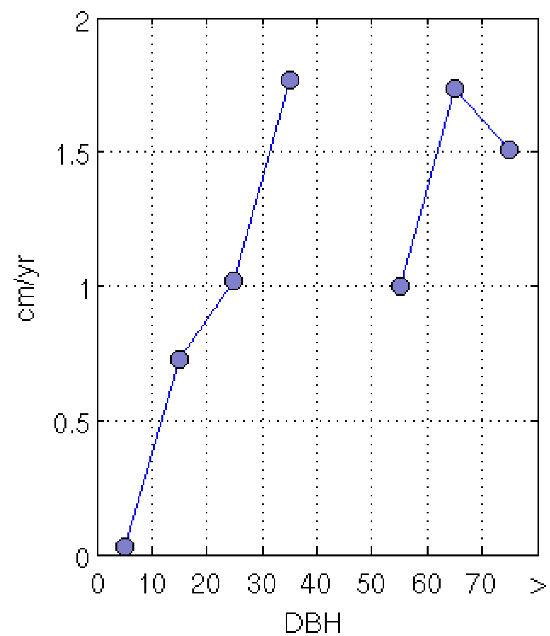


Site: Allpahuayo-Mishana A (Peru)
2005-2011

Basal Area



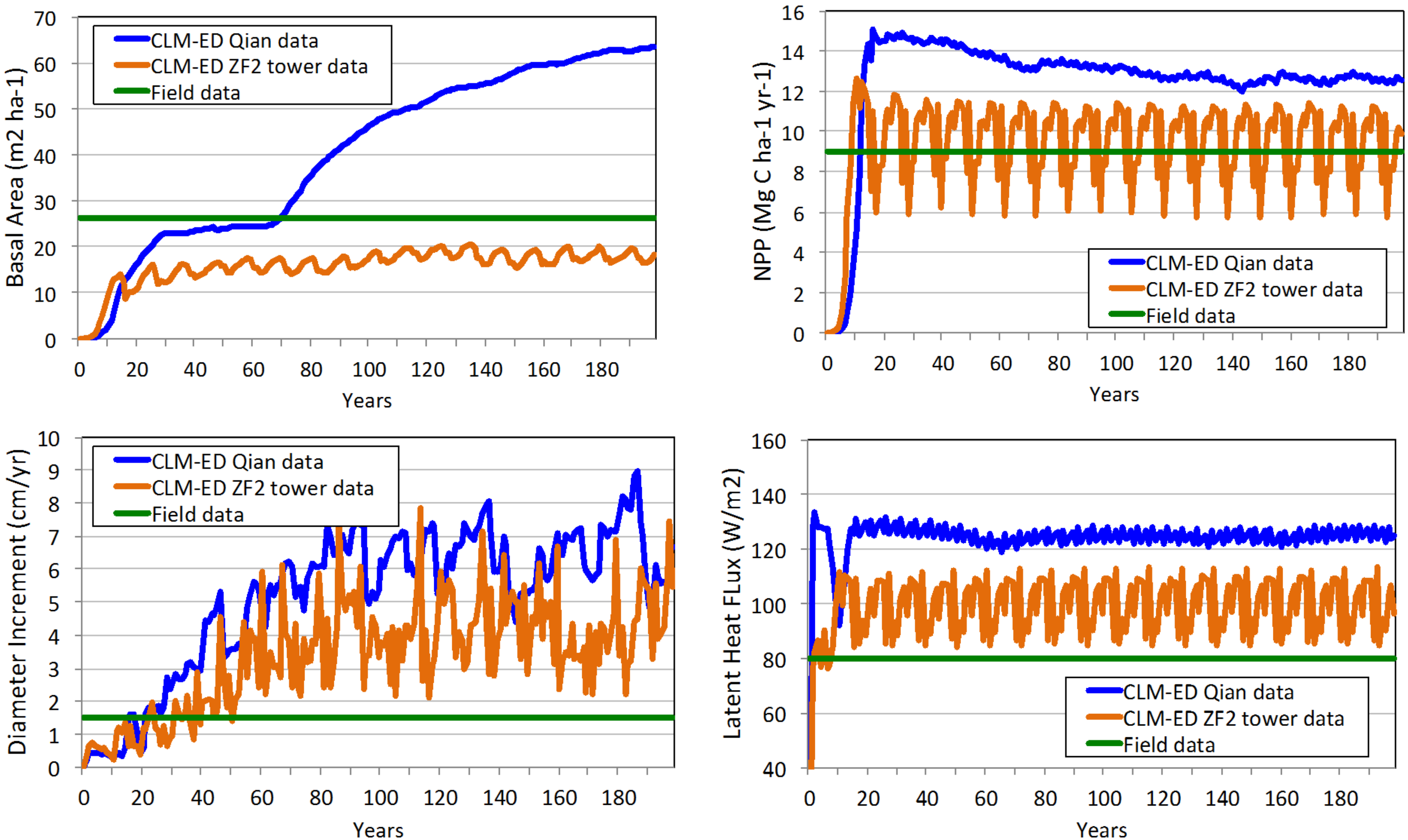
Diameter Increment



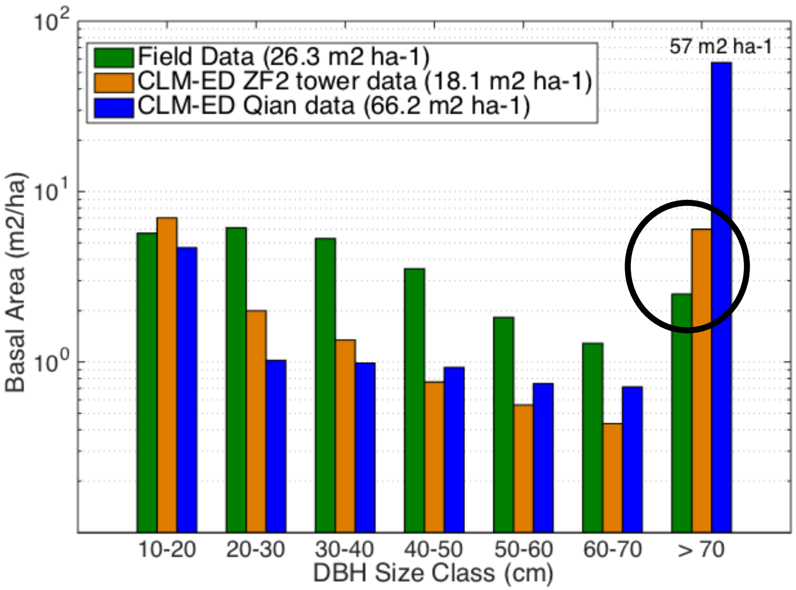
Meteorological forcing data makes a difference

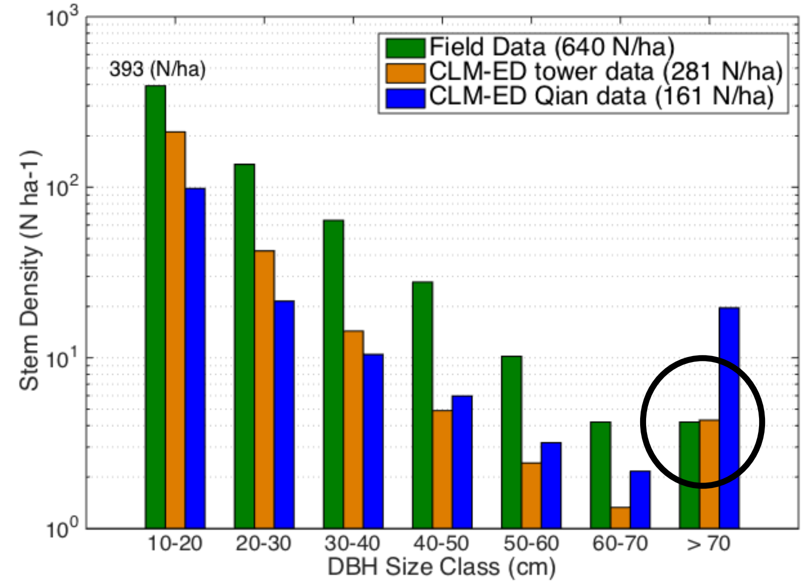
Qian vs. tower forced vs. observed

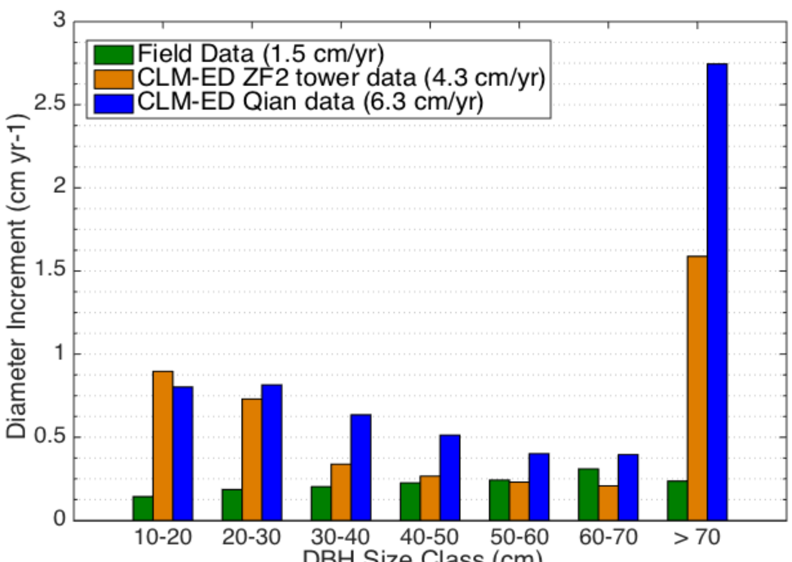
Tower data = less precip, less radiation, less specific humidity

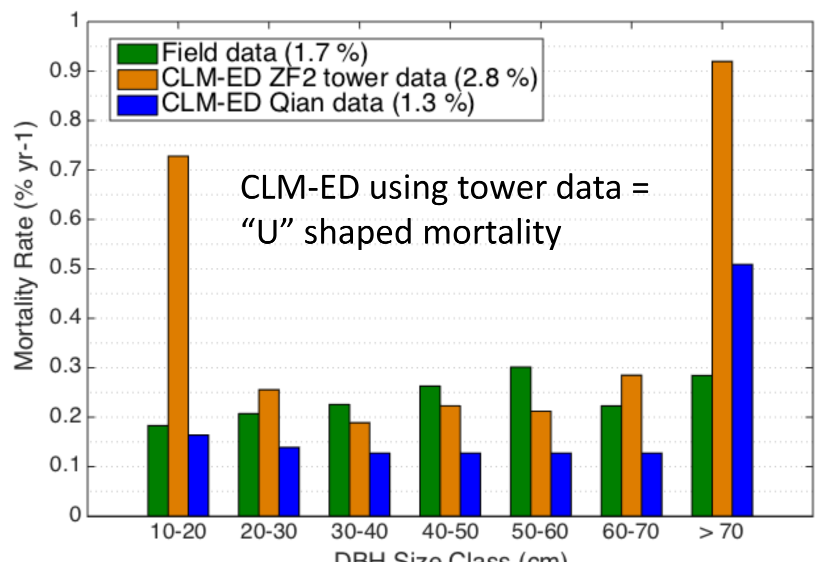


When using different meteorological forcing data, is bias towards large trees corrected? **Yes**. But, diameter increment and mortality still high.

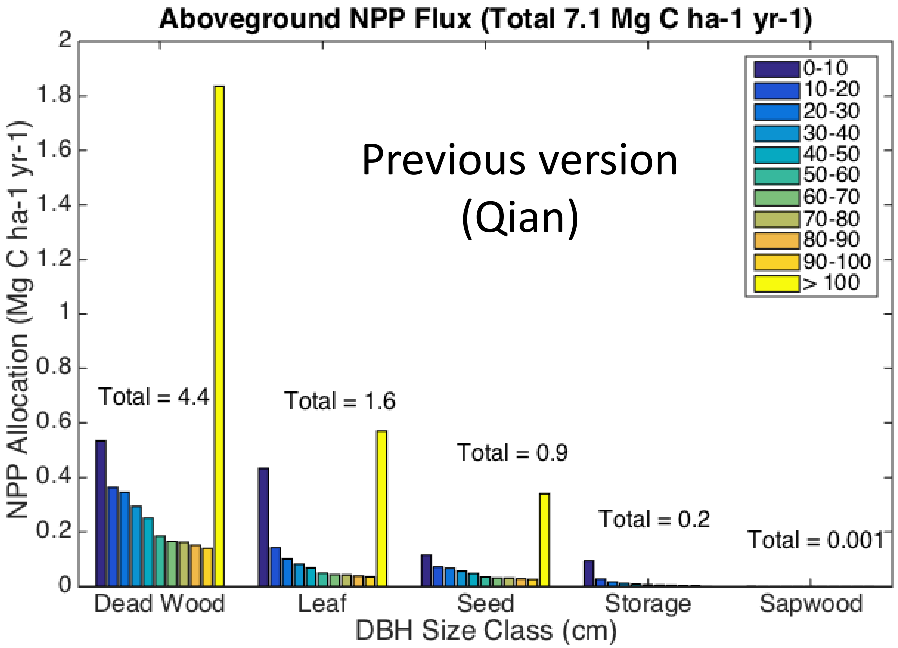


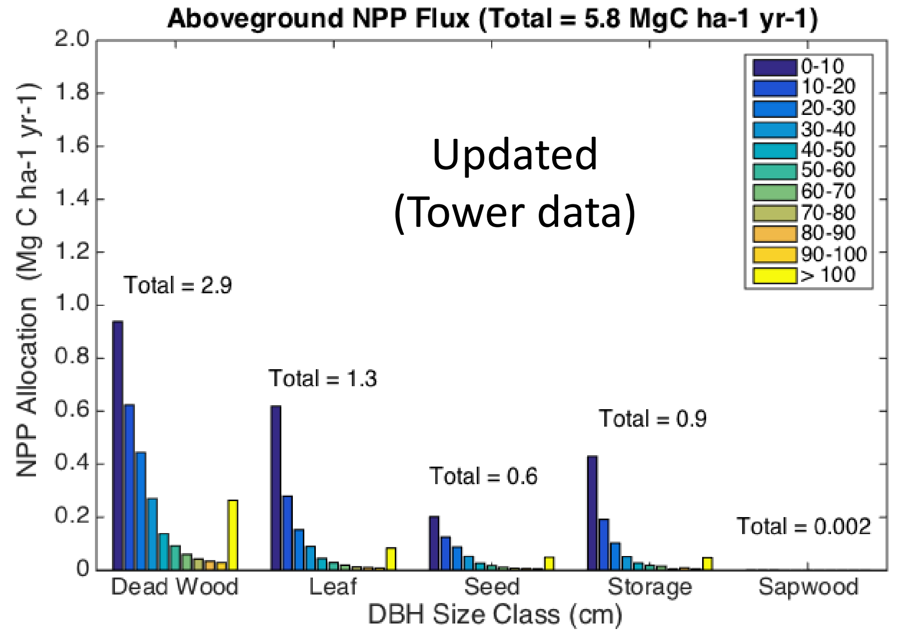






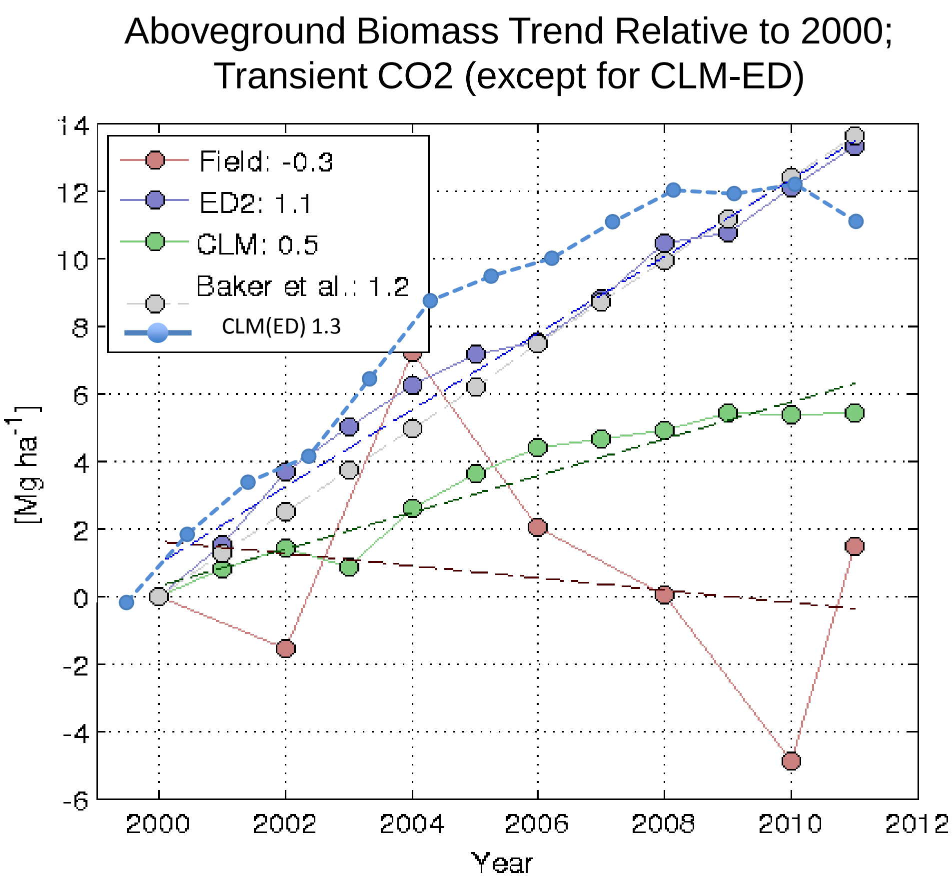
Revisit CLM(ED) NPP flux with different climate forcing

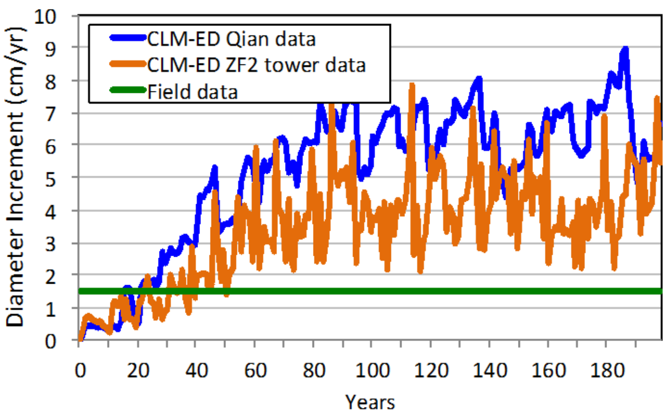


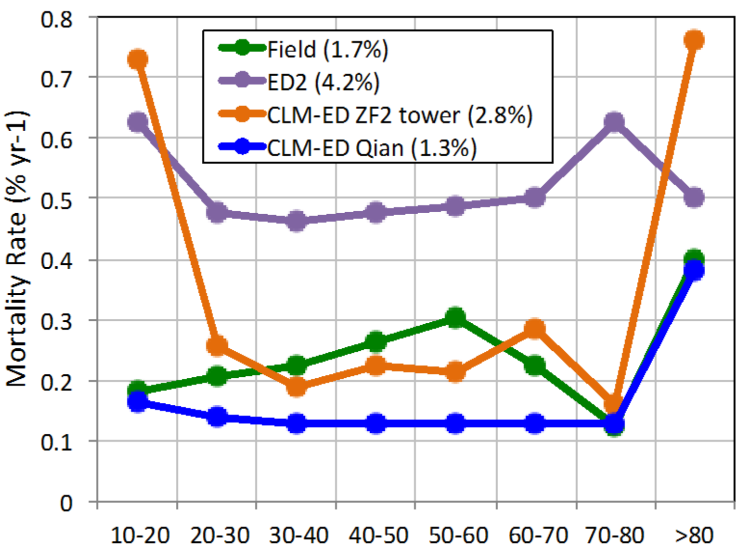


Mg C ha^{-1} yr^{-1}	CLM(ED)	CLM(ED) Tower Data	Chambers et al. 2001
Dead Wood	4.4	2.9	3.2
Leaf	1.6	1.3	3.3
Seed	0.9	0.6	NA
Storage	0.2	0.9	NA
Sapwood	0.001	0.002	NA
Total	7.1	5.8	6.5

Multiple models have bias towards faster turnover rates and larger biomass increment. Why?







What have we learned so far?

- How does CLM(ED) compare to CLM4.5 BGC?
  - Lower LAI, lower AGB to more accurate values to field data, lower sensible heat flux.
- Forest demographic patterns in CLM(ED) need some attention (i.e., size class distribution of basal area, AGB, stem density).
  - There is a bias towards large diameter trees.
  - Larger trees keep getting bigger and bigger.
  - High diameter increment and mortality rate (except for mortality when using Qian forcing data).
  - High stem density in >100cm; leading to continual NPP into larger stems.
- Different meteorological forcing datasets can lead to large differences when using an ecosystem demography model.
  - Basal Area of 18 vs. 66 m^2 ha^{-1}
  - AGB of 150 vs. 600 Mg ha^{-1}
  - Using site specific climate data correct bias towards large trees, but growth rates and mortality rates still high.
  - But using site specific climate data is not feasible in global CLM(ED).

Next steps

- Pan-tropical test-bed with suite of CLM(ED) single point runs
  - Compare against benchmarking data in Peru, Panama, Puerto Rico, Asia and more Brazilian sites
- Diagnosing bias towards large tropical trees, large BA, large AGB
  - Parameter sensitivity testing of Vcmax, NPP allocation, causes of mortality, others?
  - Investigate why high growth and mortality
- Global runs with competition between all PFTs
- Belowground nutrient constraints

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