Forest mortality and disturbance in the Community Land Model (CLM)

CESM Land Model and SDWG Meetings
Boulder, CO. February 22, 2013

Jennifer A. Holm, Jeffrey Chambers, Bill Collins
Lawrence Berkeley National Lab

Disturbance and Climate Change

letters to nature

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Climate-induced changes in forest disturbance and vegetation

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nature climate change

Consequences of widespread tree mortality triggered by drought and temperature stress

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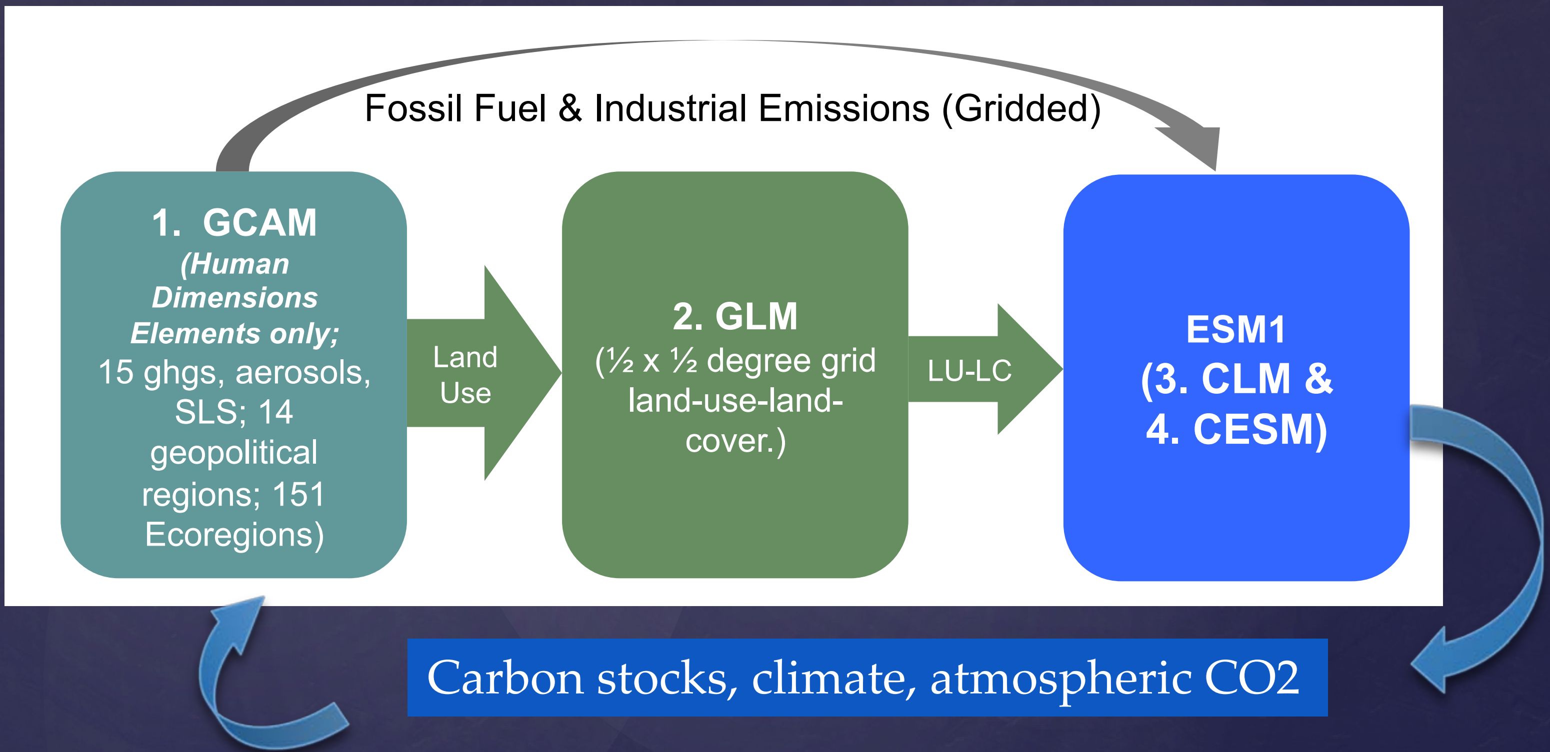
Forests provide innumerable ecological, societal and climatological benefits, yet they are vulnerable to drought and temperature extremes. Climate-driven forest die-off from drought and heat stress has occurred around the world, is expected to increase with climate change and probably has distinct consequences from those of other forest disturbances. We examine the consequences of drought- and climate-driven widespread forest loss on ecological communities, ecosystem functions, ecosystem services and land–climate interactions. Furthermore, we highlight research gaps that warrant study. As the global climate continues to warm, understanding the implications of forest loss triggered by these events will

Articles

Big Picture - iESM Collaboration



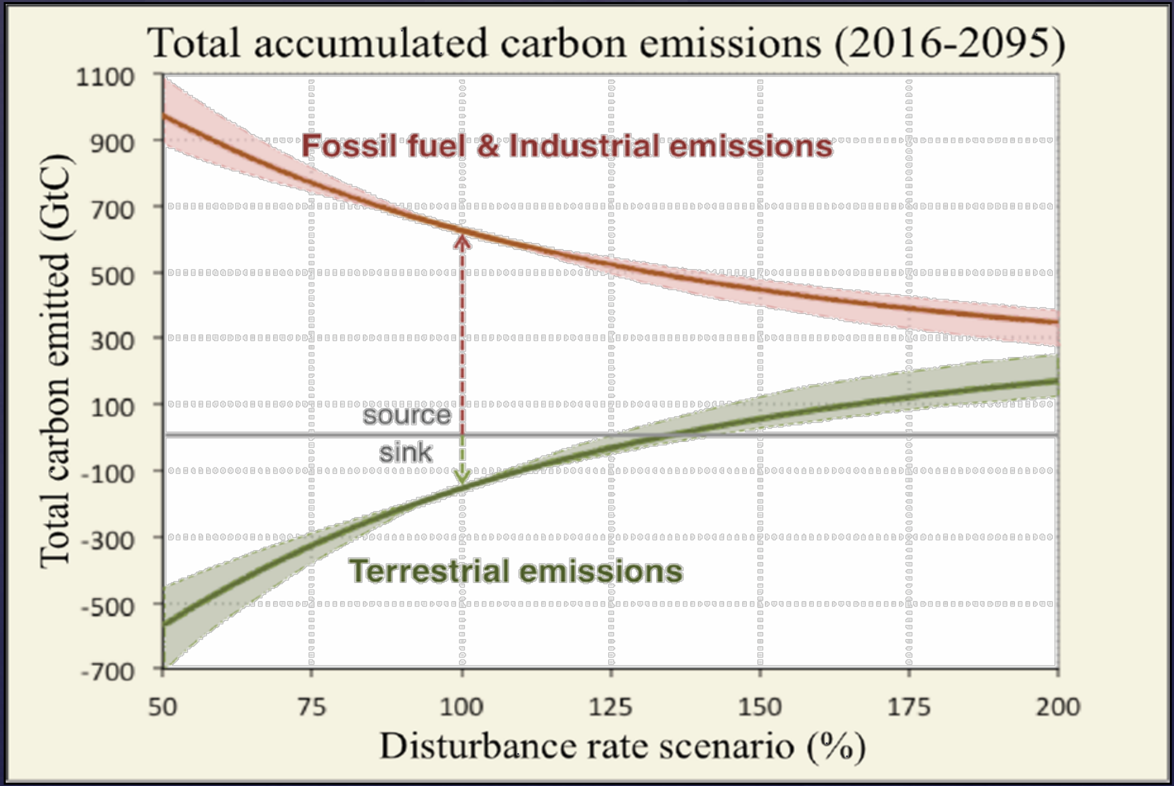
Integrated Earth System Model (iESM)

Links human components and physical/climate modeling of an Earth System Model

Goal - Improve knowledge of coupled physical, ecological, and human system.

iESM Collaboration

Yannick LePage's and George Hurtt group (submitted)
Analysis in GCAM – Global Change Assessment Model
(Dynamic economy, energy, and land use model)

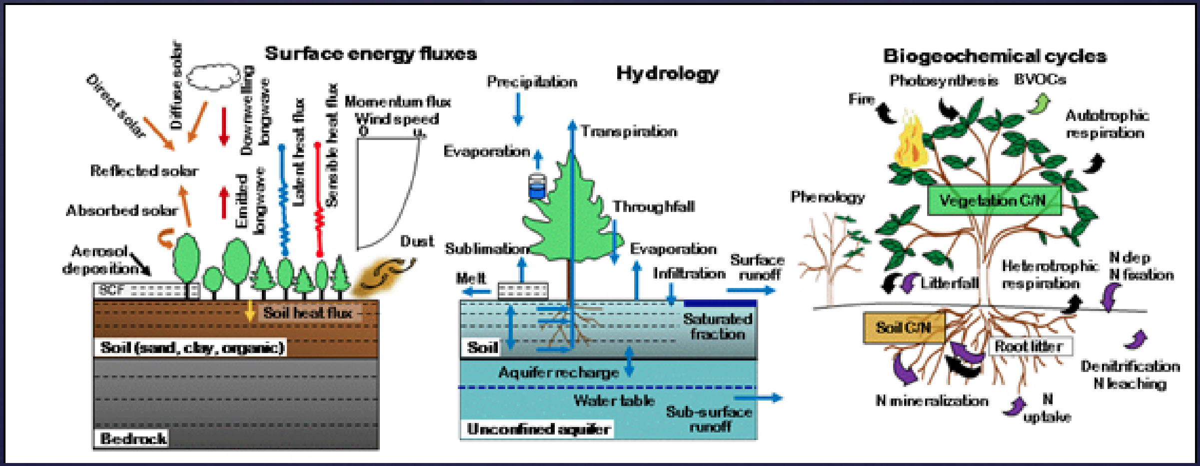


CLM within iESM

Uniqueness – only working within CLM component (biogeochemistry)

Questions –

1) What are the long-term consequences and differences in terrestrial fluxes with increasing disturbance (i.e. doubling mortality rates) in a tropical forest?
2) Big Question - Eventually, how does the carbon market and energy market respond to increased disturbances in the fully coupled iESM?(looking at the human-natural system interface)



Vegetation mortality algorithm within CLM

Needs to be improved.

- Default constant mortality rate for all PFT's across the globe – 2%
- Option 1 - Calibrate mortality rates to specific sites based on inventory data (ex. Hudiburg et al. 2013)
- Other answers for generating a more dynamic, stochastic global mortality algorithm?

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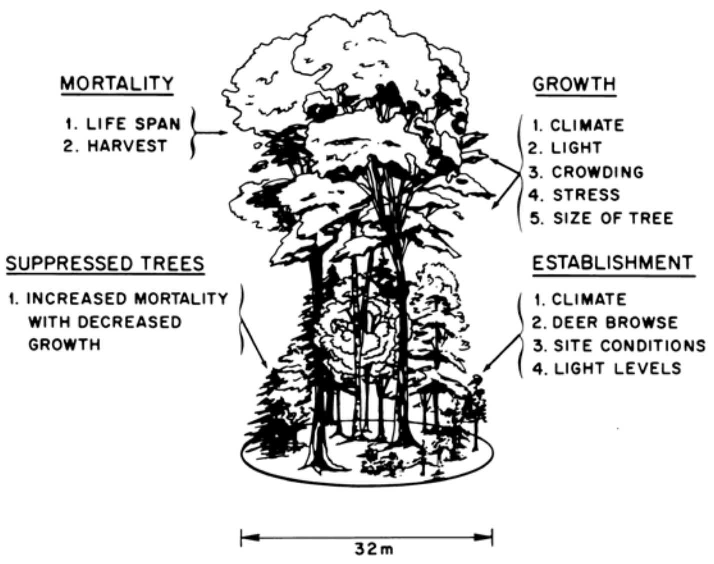
doi:10.5194/bg-10-453-2013

Gap model approach to improve CLM (also can't forget CLM-ED)



- Framework: Simulates growth, mortality, regeneration, and competition of individual species
- Optimal growth in constrained by available light, soil fertility, soil moisture, temperature.
- Individual plants modify the existing environmental conditions.
- CLM(ED) – Ecosystem Demography Model (Rosie Fisher, Gordon Bonan group)
- Individual based model with change in plant density = growth in stem – grow in active tissue – aging of plant community - mortality

Mortality in ZELIG (gap model)

1) naturally caused death (age-related), 2) stress induced death, 3) disturbance.

- Growth-mortality relationship
- Advantage – simple, yet dynamic stochastic functions. Does not assign mortality to any specific cause but based on plant level, stand level, and landscape scale.

$$P_m = 1 - e^{\left[-\frac{4.605}{age_{max}}\right]}$$

$$P_S = RDI < 0.10 * (Dmax/AgeMax) \quad \& \quad P_S = 0.368$$

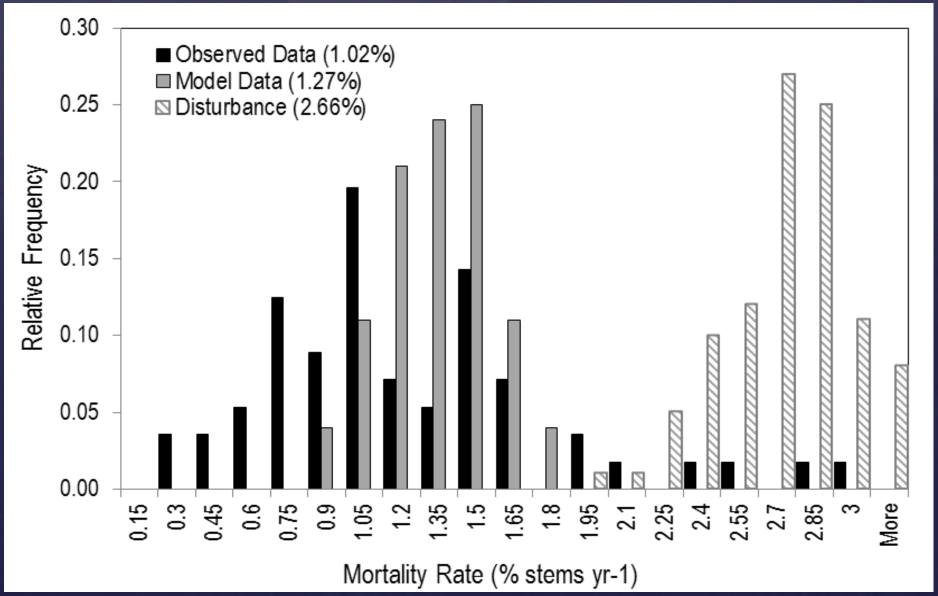
- ED Mortality – 1) longevity of plant functional type and 2) carbon balance

- Concerns within both models….growth vs. storage…

Demographic model of the Amazon – ZELIG test case with disturbance

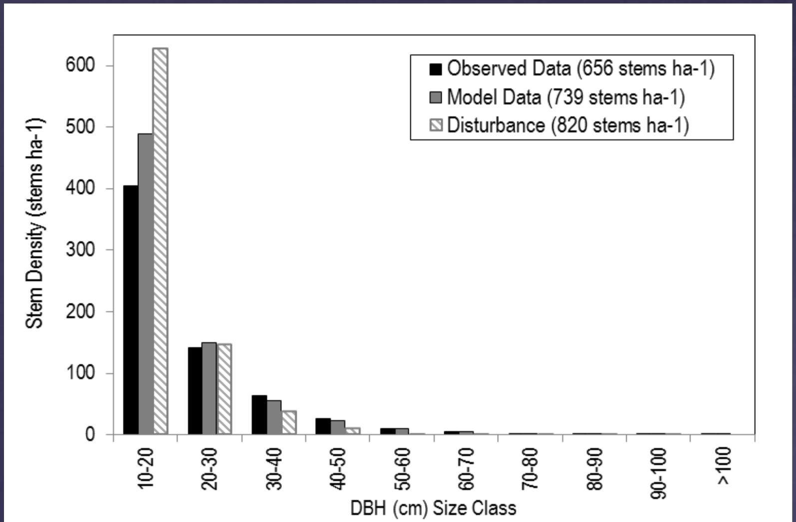
	Avg. Basal Area (m2 ha^{-1})	Avg. Biomass (Mg ha^{-1})	Avg. Stem Density (ha^{-1})	Avg. LAI	Avg. NPP (Mg C ha^{-1} yr^{-1})
Field Data	30.06 (6.61)	339.68 (27.60)	656 (22)	5.7 (0.50)	6.5
ZELIG-TROP	29.14 (1.08)	327.94 (26.46)	739 (245)	5.8 (0.24)	6.3 (0.89)
Percent Diff. (%)	-3.11	-3.52	11.90	1.74	-3.13
ZELIG-TROP min./max.	27.53/31.79	279.74/378.52	321/1233	5.26/6.48	5.05/7.89

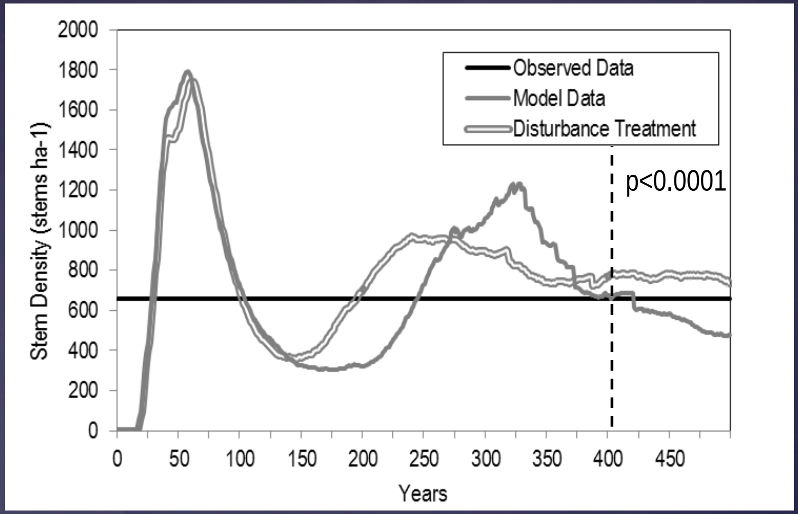
Successful replication of tropical forest attributes (Basal area, Biomass, Stem Density, LAI, NPP)



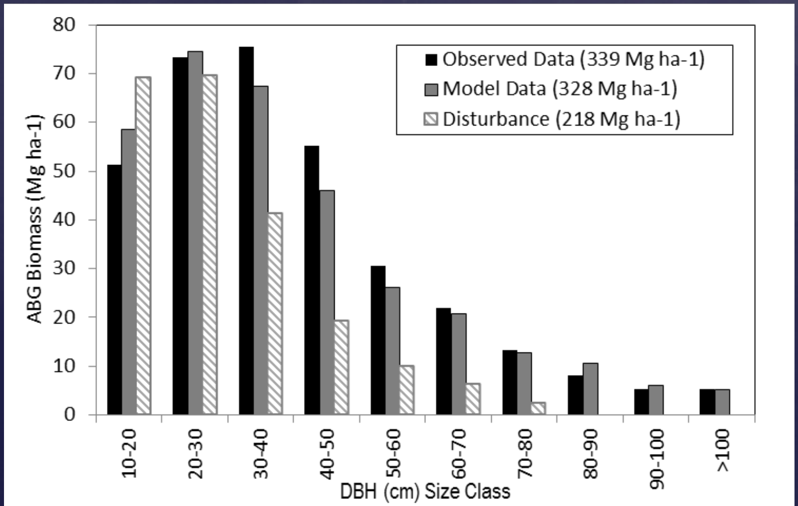
no disturbance vs. high disturbance

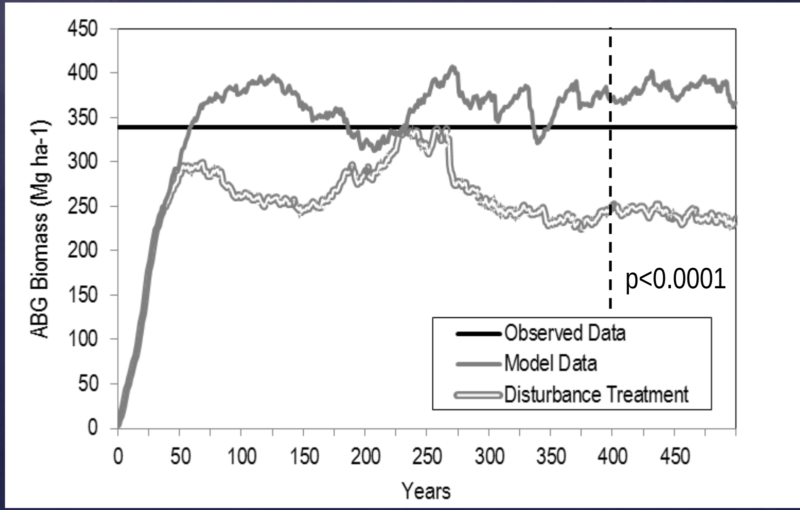
Impacts of high disturbance in the Amazon





34% increase in stems



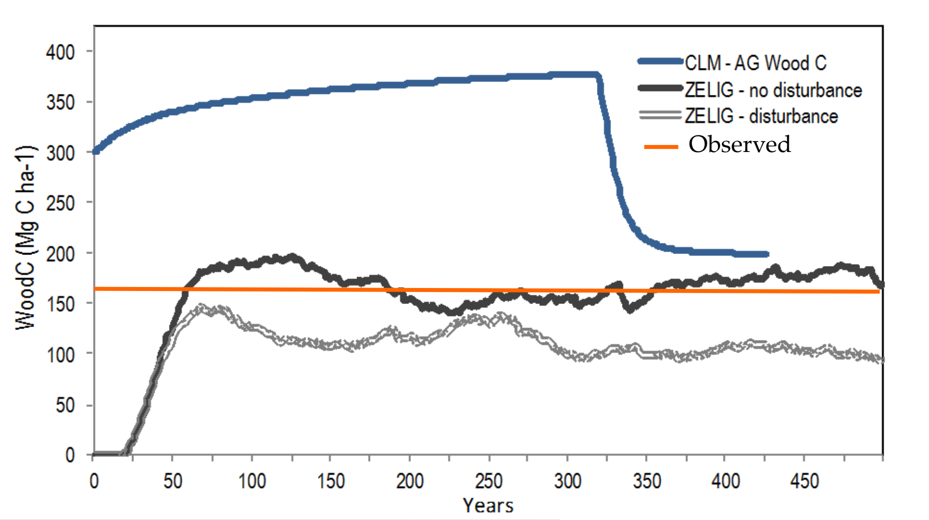


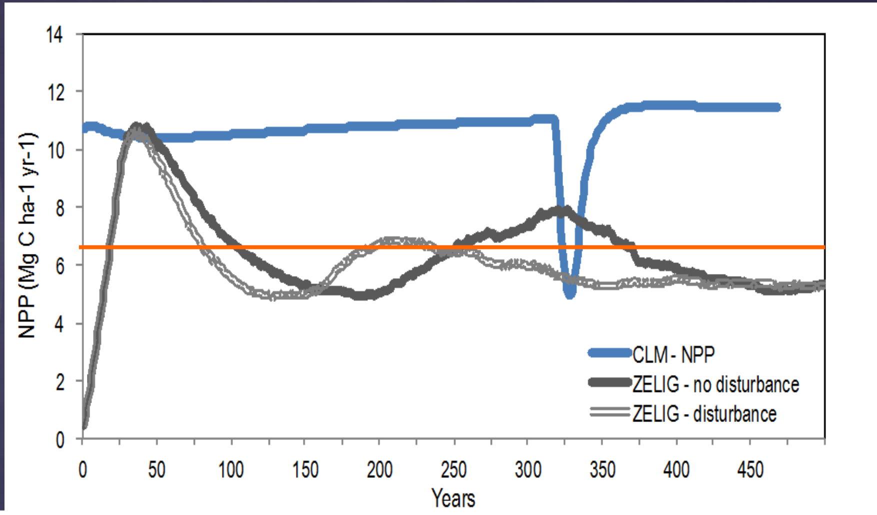
42% decrease in biomass

ZELIG vs. CLM4-CN (Amazon test case)

Used stand-alone active land model with re-analysis (Qian) atmosphere data for 2003, CO2 level for 2000

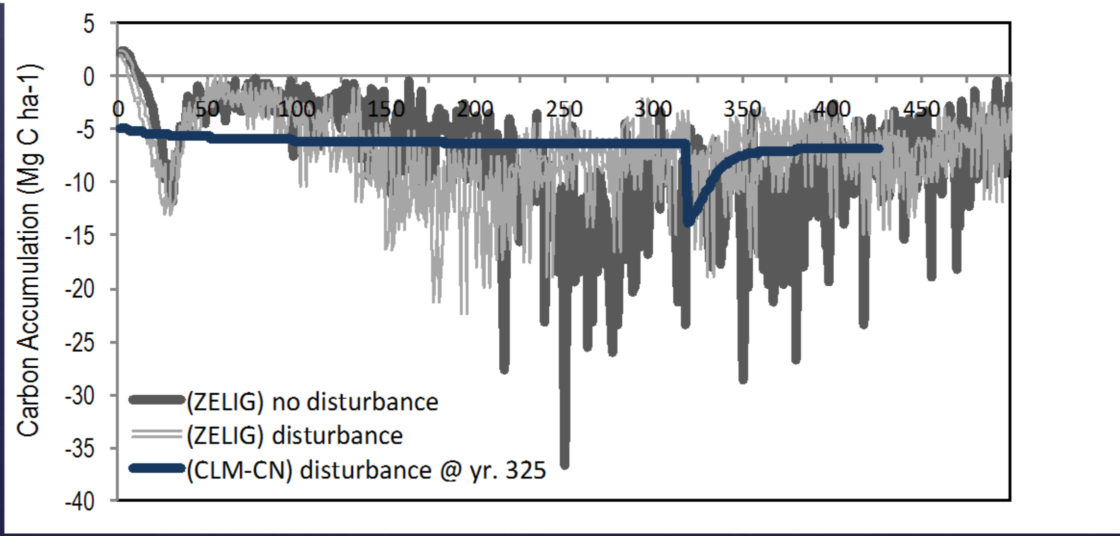
CN model, no fire





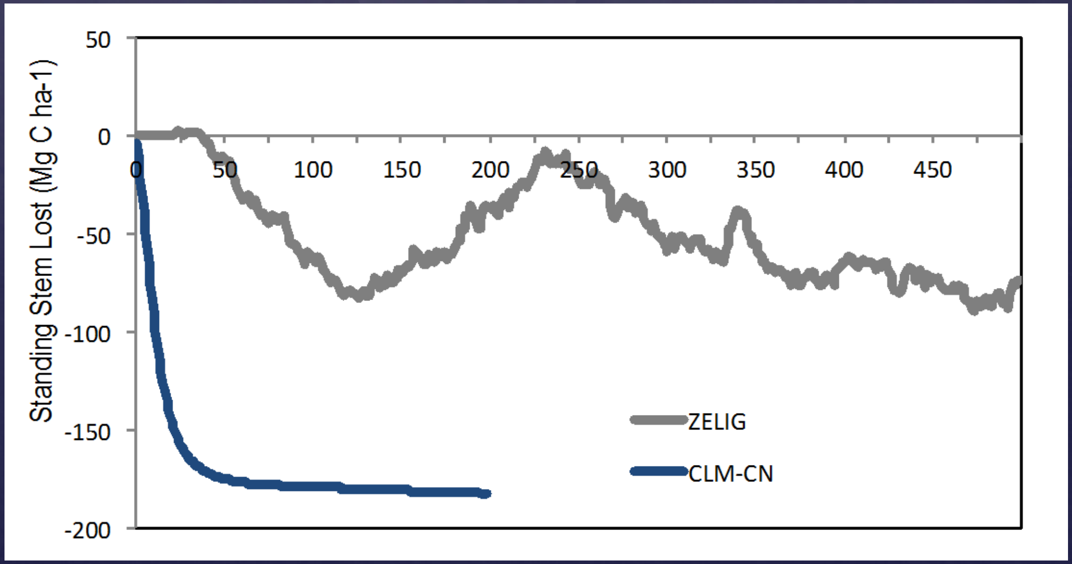
Simple above-ground carbon accumulation = live stem c – AG woodC loss

(negative = source)



	Empirical	Chambers et al. 2004 Model	ZELIG No Disturbance	ZELIG Disturbance	CLM No Disturbance	CLM Disturbance	ZELIG Relative Difference (%)	CLM Relative Difference (%)
Live Trees (Mg C ha-1)	156	160	164	109	377	199	101.08	99.80
Growth (Mg C ha-1 yr-1)	1.7	1.6	2.5	2.4	1.06	1.08	0.16	-0.01
Mortality (Mg C ha-1 yr-1)	-2.1	-1.7	-10.39	-9.7	-7.52	-7.89	-1.27	0.21
Turnover (% yr-1)	1.5	NA	3.0	5.2	NA	NA	NA	NA
Mean DBH (cm)	21.1	20.4	22.3	18.3	NA	NA	NA	NA
Total (Mg C ha-1 yr-1)	155.6	159.9	156.1	101.7	370.54	192.19	100.0	100.0

Standing live stem lost after disturbance treatment (Mg C ha^{-1})
Gap model – dynamic response was captured
CLM – static response



Concluding thoughts and future steps…

Can a gap model be a "benchmark" for improving CLM and global models?

- Match between observed forest characteristics and processes

Interaction between CO_2 fertilization and increased disturbance on carbon fluxes

My next steps –

1) Including evaluation between ZELIG, CLM, and CLM-ED
2) Use CLM 4.5 and modify mortality algorithm
3) Integration of new mortality algorithm and changes to disturbance in iESM