Land-climate interactions and the GFDL new land model LM4

Presented by E. Shevliakova

cross-GFDL, Princeton University/ NOAA Cooperative Institute, USGS, and other collaborators

Geophysical Fluid Dynamics Laboratory Review

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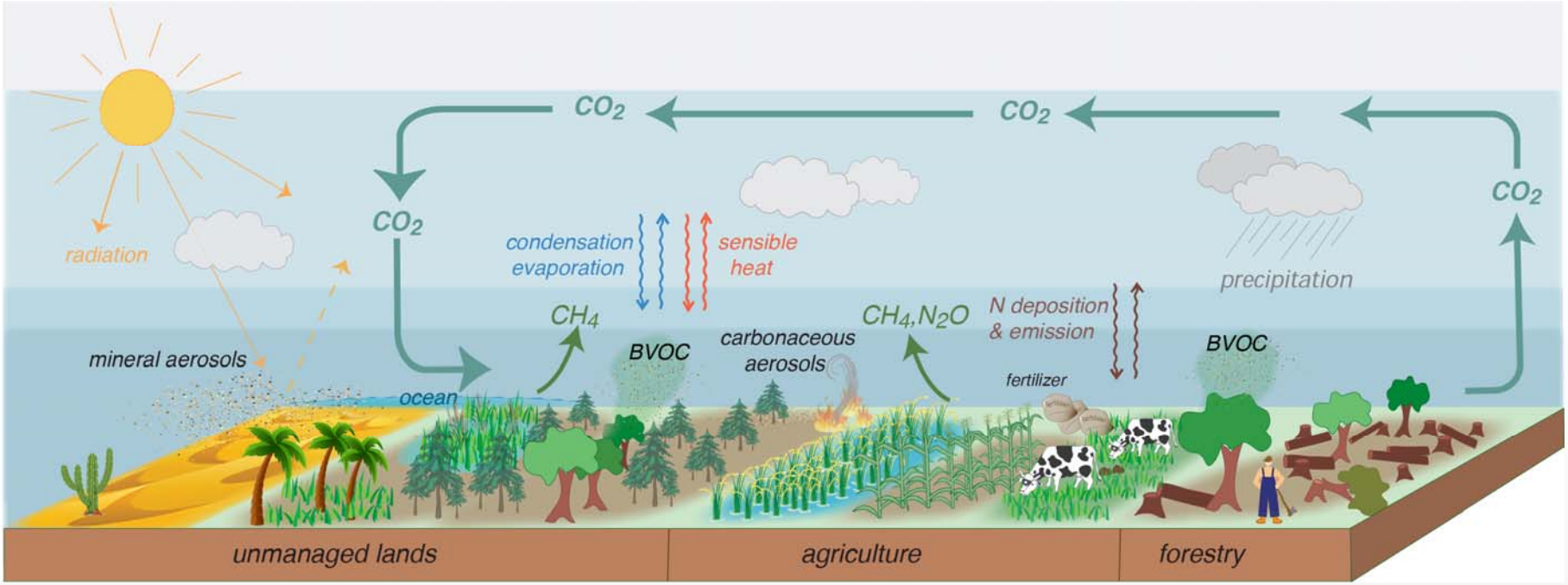
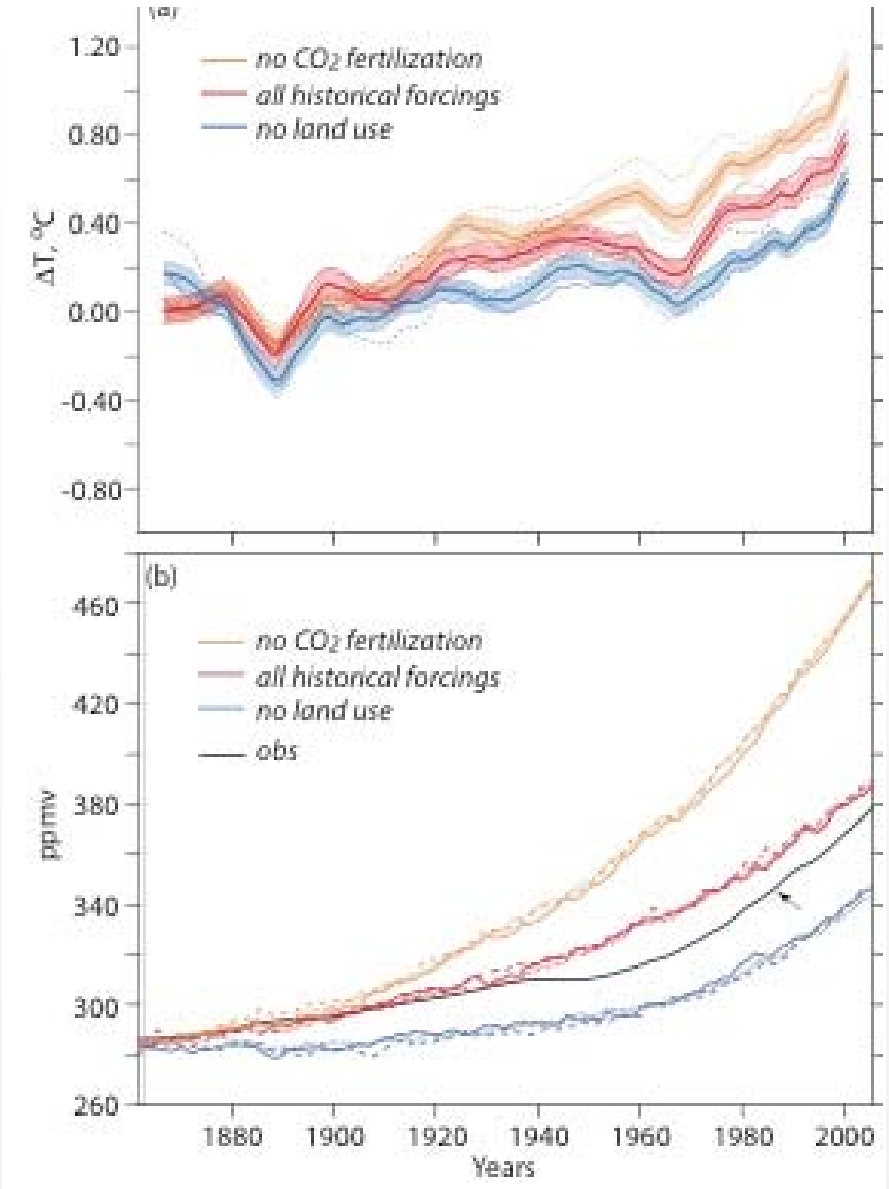
GFDL land models in ESM framework



- We live on land and we change land more than any other Earth component.
- Land is warming nearly twice as much as the globe since preindustrial.
- Land is a sink and source of carbon – depend on the rate of forest growth.
- Regional climate change depends on land properties and feedbacks.

Land-climate interactions in GFDL ESM2G



- Land use emissions contributed ~30 ppm to 2005 atmospheric CO_2 increase.
- The net biogeochemical and biophysical effect of land use change was +0.17 ± 0.06 °C.
- Without enhanced vegetation growth in 2005 atmospheric CO_2 would have an additional 85 ppm and global surface temperature would be 0.31±0.06°C warmer.

Shevliakova et al. 2013

Parallel streams of LM4 Development

	Veg dyn.	Plant H_2O	Land use	Soil H_2O	Soil C	N cycle	Dust	Fire
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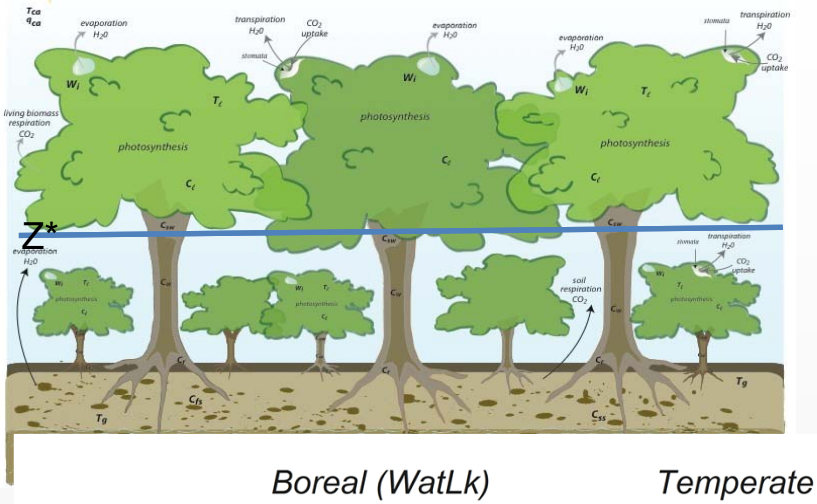
ESM4 ecosystem demography:

we can see the forest and the trees in LM4.1

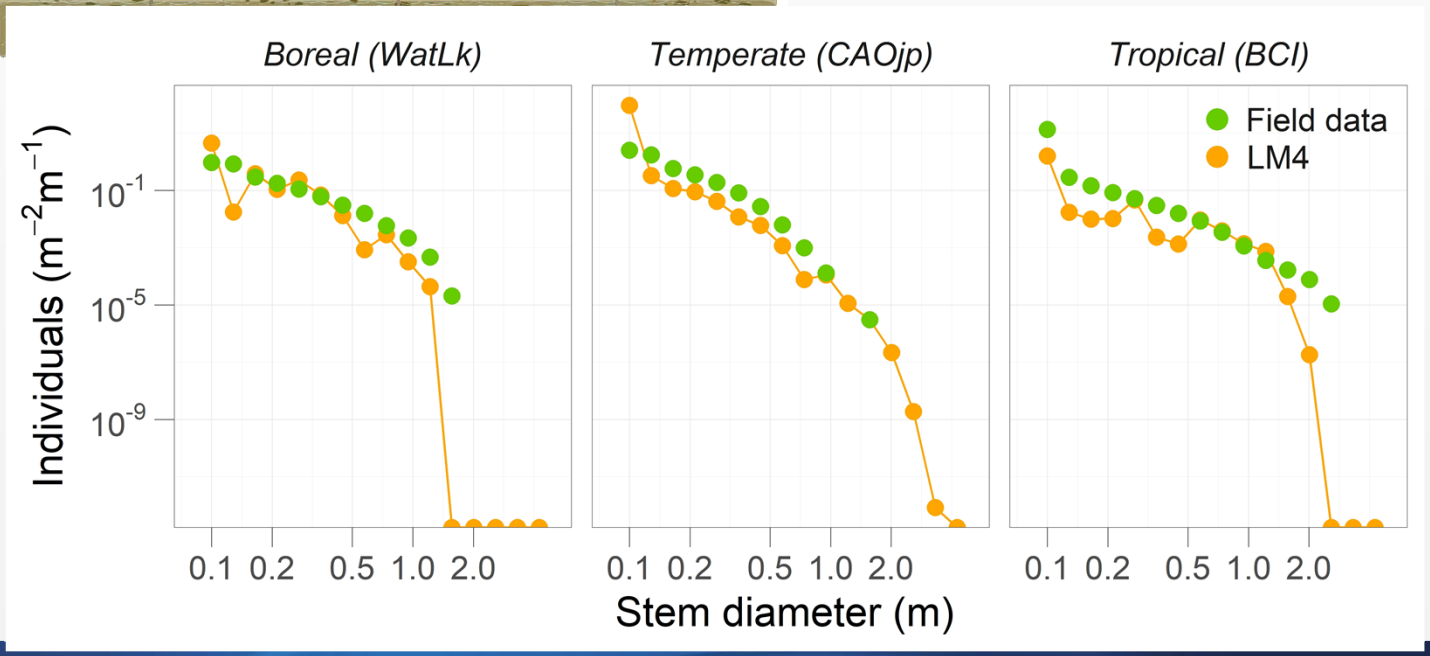
Tree cohorts with multiple individuals (stems)



Perfect Plasticity Approximation

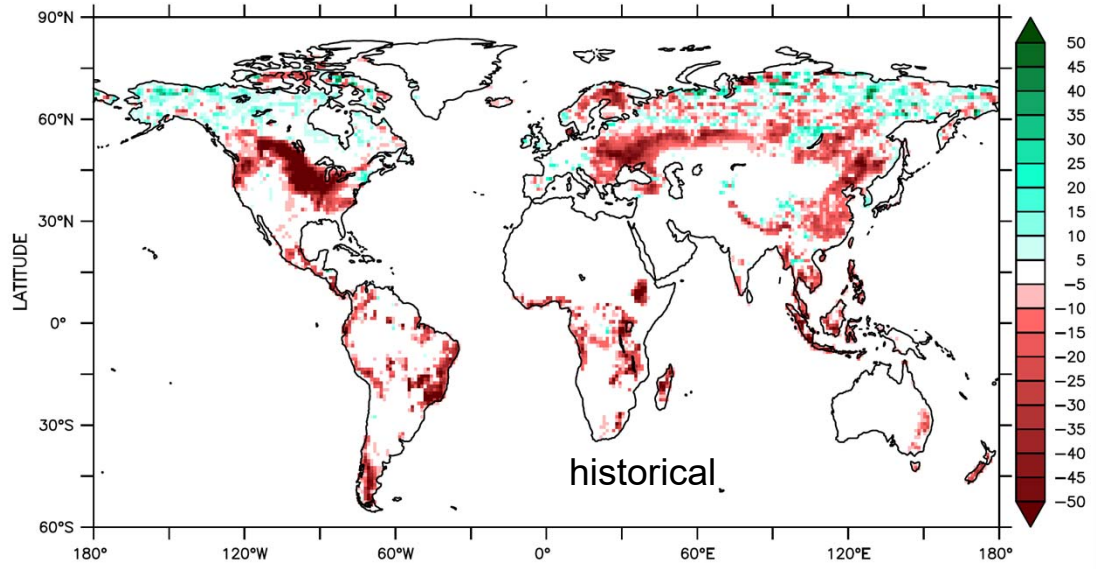
In collaboration with Pacala lab, we addressed major DGVM challenges:

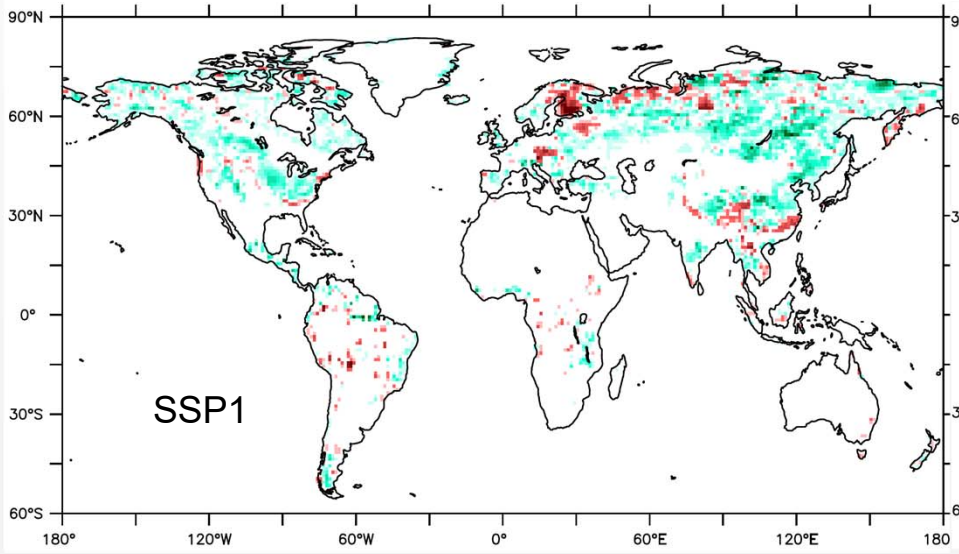
- *no unrealistically large "trees"*
- *plants compete and coexist*
- *vegetation succession and age*
- *land use interactions*

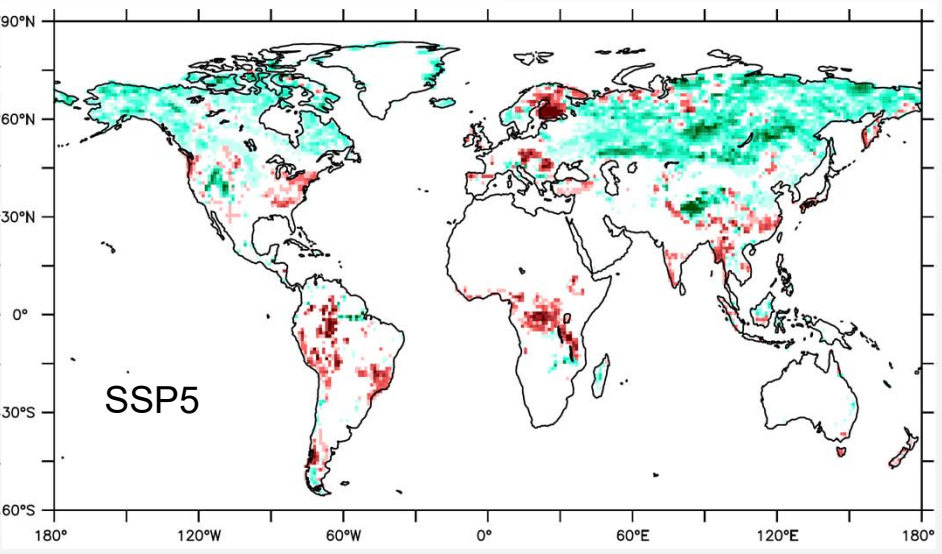


Martinez Cano, in prep
Weng et al, 2015
Strigul et al, 2008

Projections of changes in tree cover, ESM4







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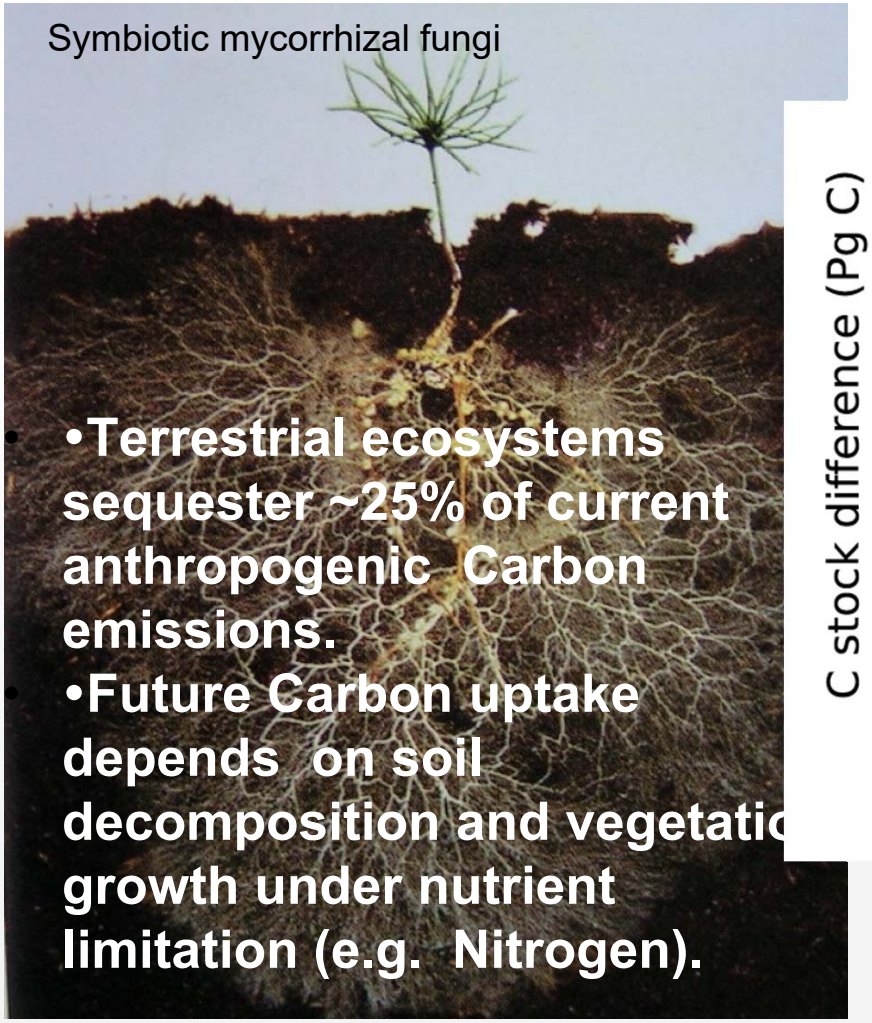
Novel LM4 mechanisms: symbiotic fungi

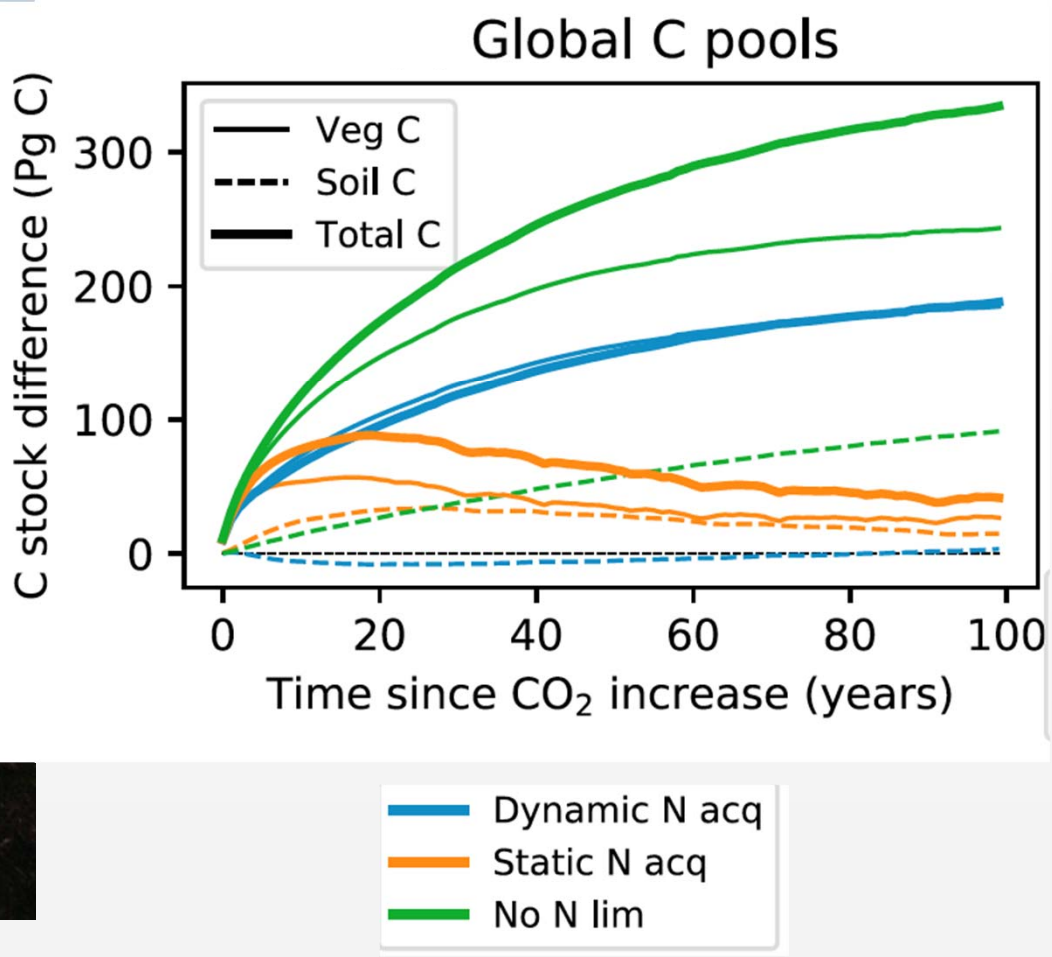
Symbiotic mycorrhizal fungi



- •Terrestrial ecosystems sequester ~25% of current anthropogenic Carbon emissions.
- •Future Carbon uptake depends on soil decomposition and vegetatic growth under nutrient limitation (e.g. Nitrogen).

rootrescue.com

Changes due to a 100-ppm increase in atmospheric CO2 concentration



Sulman, Shevliakova et al., 2019

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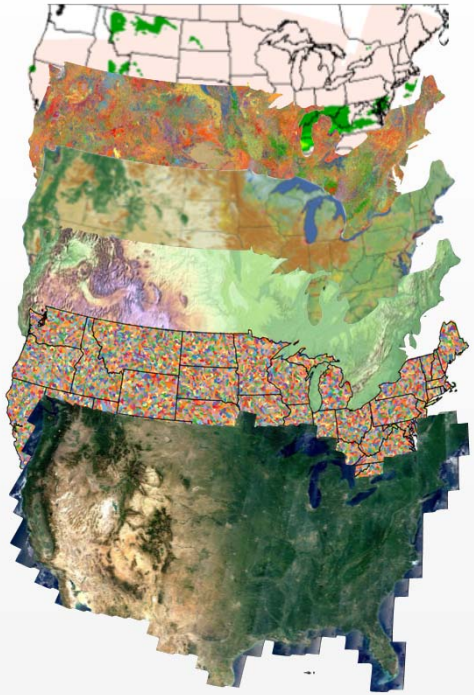
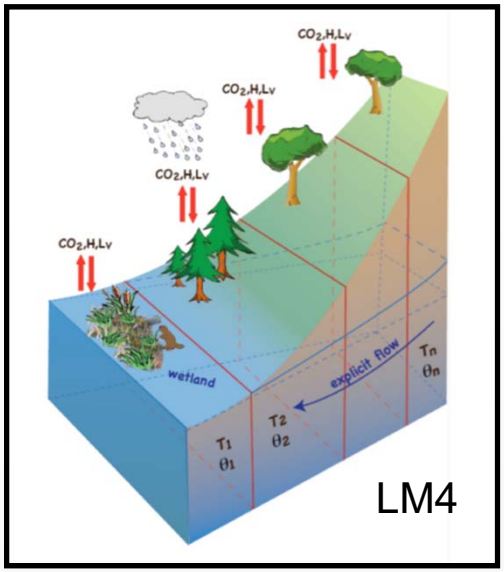
LM4.2	simple	Leuning stomata	LULCC	**Hydro-blocks Irrigation (*Y Zeng*)**	2-box Century			annual

LM4.2: capturing 30m-scale water heterogeneity

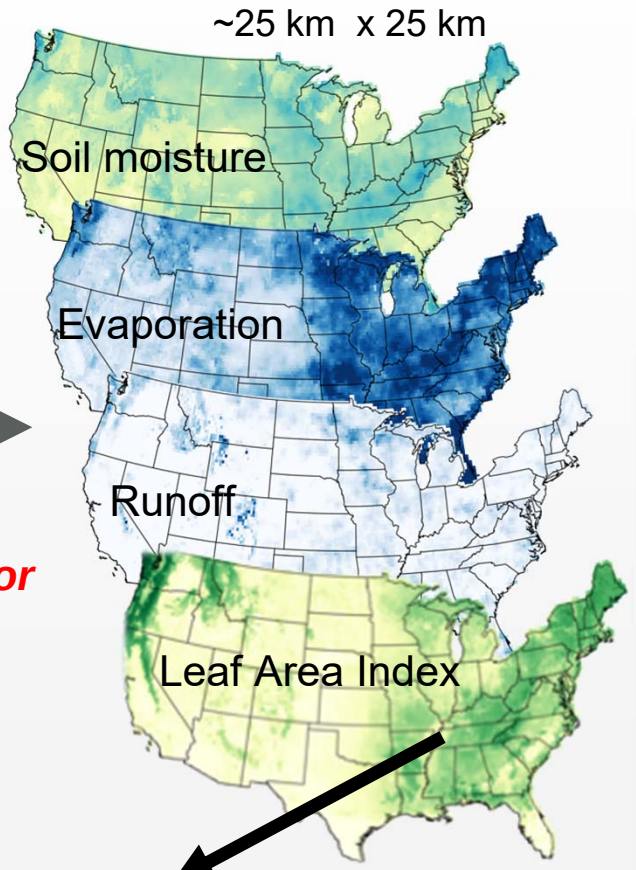
Environmental data



Hydro-blocks



Simulations



The model can provide information about ecosystems at a forest plot or a farm scale!

Chaney et al, 2018

- Land model run on a 1/4 degree grid over CONUS
- ~100 tiles per 1/4 degree grid cell (~13000 cells)
  - ~1.5 million different tiles over CONUS
  - Each 30 meter grid cell belongs to a tile
- Simulations between 2002 and 2014 (Spin-up 1974-2001)

Enhancing future predictions and projections

	Veg dyn.	Plant H_2O	Land use	Soil H_2O	Soil C	N cycle	Dust	Fire
ESM4-N (LM4.#)	**PPA 2nd gen**	**Wolf stomata, plant H_2O**	LULCC+ **Irrigation urban**	**Hydro-blocks**	**CORPSE Microbes C-N**	**Plant-soil-river C-N;**	**Land emis. /depos.**	**Daily interactive New tiles**

Ongoing and new developments:

- coastal land ecosystems and estuaries;
- collaboration with EMC on LM4 in UFS;
- two new land CPTs: boundary layer and radiation exchanges over heterogeneous land;
- land-atmosphere coupling: BVOC emissions, CH_4;
- land data (e.g. water and carbon) assimilation;
- Phosphorus cycle.

Going forward

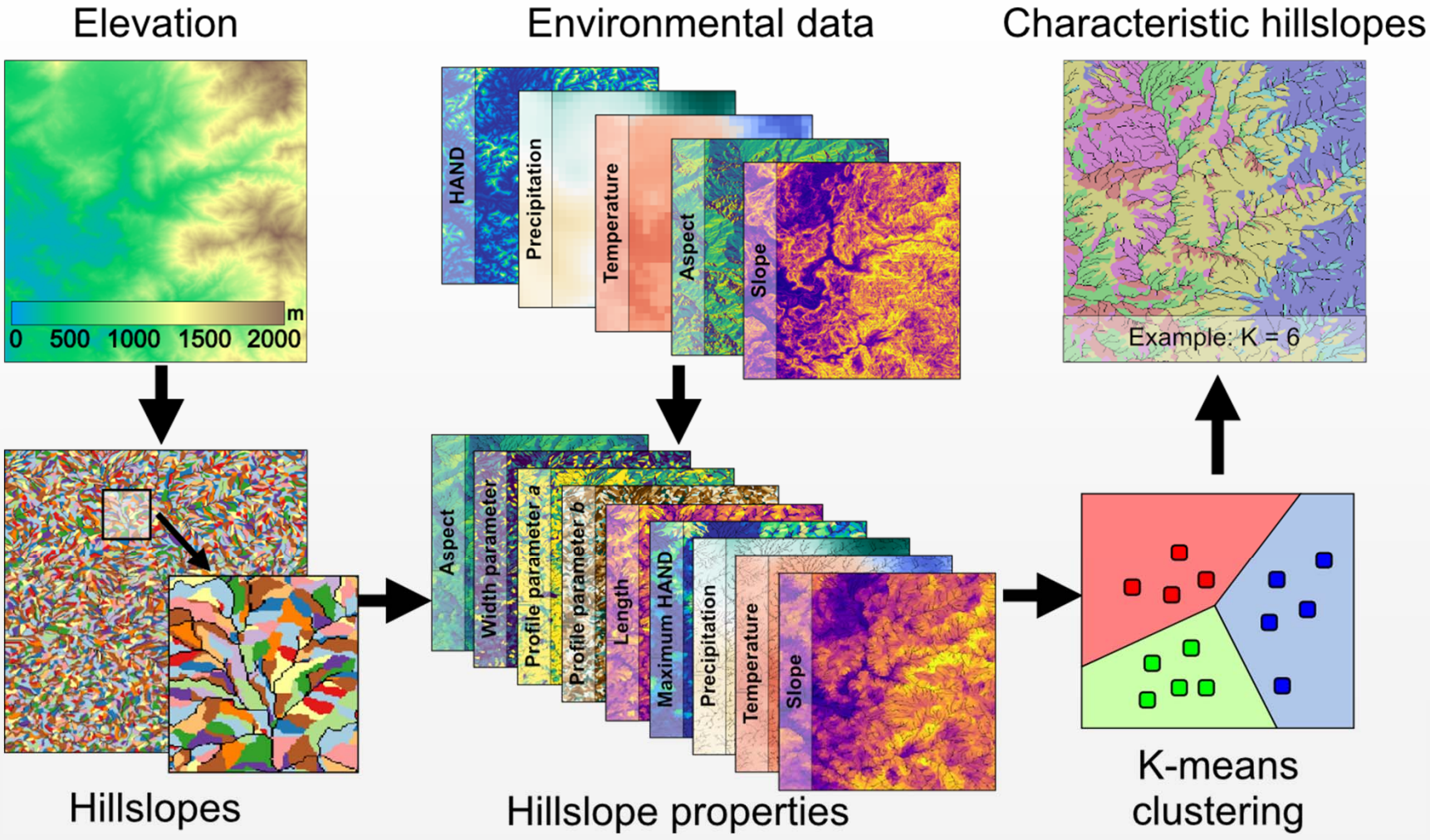
We have an outstanding portfolio of new land modeling capabilities and their applications to address NOAA mission

Challenges:

- computing constraints with current HPCS
- evaluation and new processes
  - new climate and ESM process teams are essential!

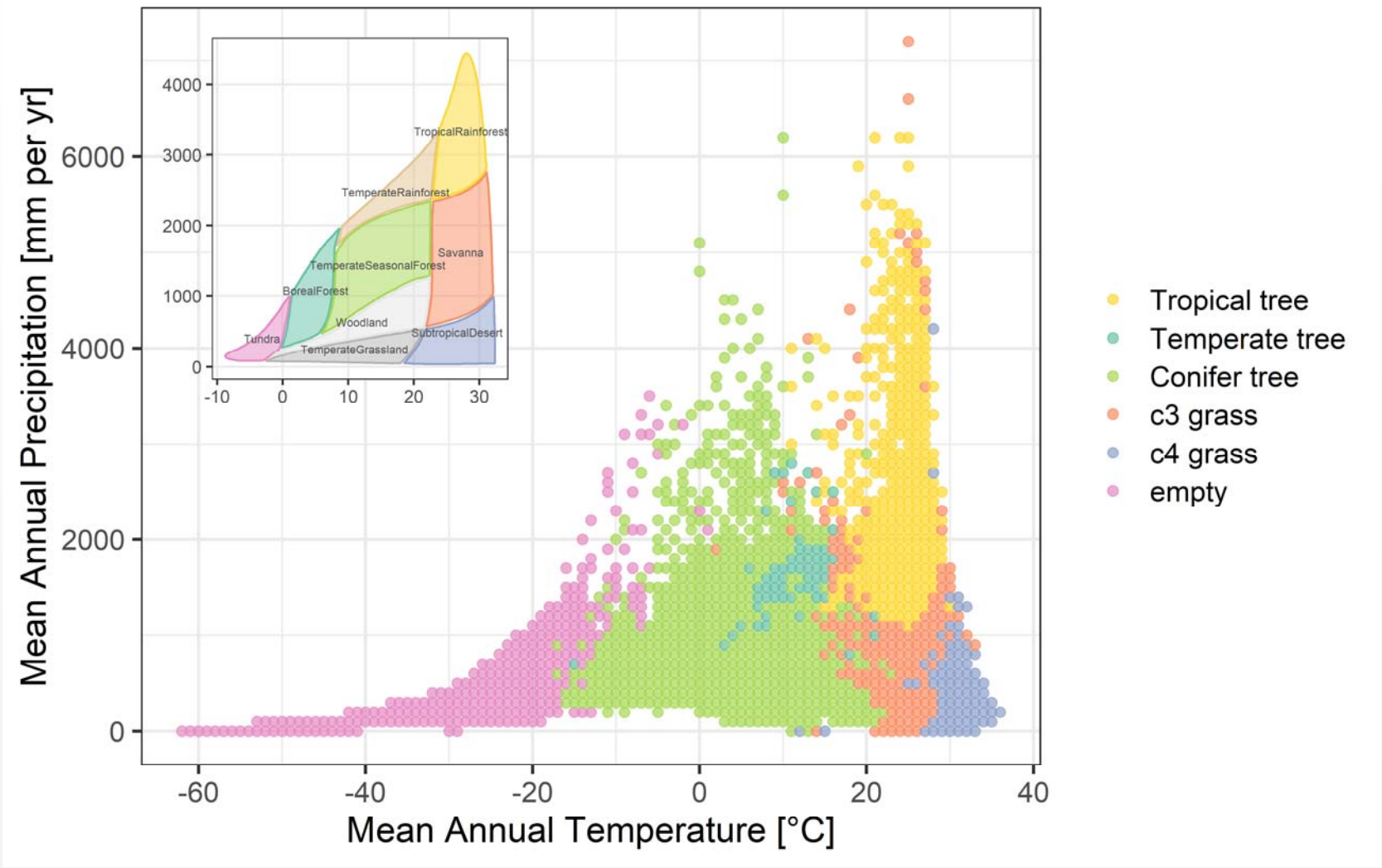
EXTRA slides

LM4.2: Leveraging petabytes of data to define land heterogeneity



Chaney et al., 2018

Plants - climate association in ESM4



Courtesy of Martinez Cano