CCI+ Biomass First User Workshop

Climate Models Requirements for Biomass Observations

P. Ciais and D. Goll

Thanks to LSCE, U Leicester and U. Sheffield colleagues

Role of biomass in Earth System Models

- Main storage pool of natural and anthropogenic carbon
- Net biomass loss amplifies climate change
  - CO_2 emitted to the atmosphere
  - Acceleration of the turnover of C (reduced sink potential)
  - Biophysical effects (different sign in different regions, warming from tropical deforestation and cooling from boreal deforestation)
- Concerns about tropical biomass stability
  - The large size of the tropical forest biomass pool represents a risk of significant positive feedback on climate change

Accurate modelling of biomass in Earth System Models is key for:

- Historical carbon budget
  - land use emissions,
  - land sink in natural ecosystems
- Future evolution of the coupled carbon-climate system
  - Negative feedback : biomass partly sets carbon turnover, hence future sink potential in natural ecosystems
  - Biomass loss accelerates warming
  - Low warming scenarios assume large-scale deployment of forest plantations for carbon dioxide removal (net effect on climate and carbon cycling poorly understood).

Biomass representation in Earth System Models

- Processes that cause biomass changes in <u>models</u>

Processes	Degree of complexity in current ESMs	Level of confidence
Photosynthesis:		
Phenology (more leaves) *e.g. longer growing seasons*	+	medium
Physiology (more efficient canopy) *e.g. CO_2 fertilization , diffuse light …*	+	medium
Carbon use efficiency, plant respiration	- -	low
Carbon allocation	- -	low
Background mortality	- - -	low
Fire disturbance	-	low
Land cover change disturbance	+	low

- Processes causing biomass changes in <u>real world</u>

Processes ≈ included in ESMs
Photosynthesis
Phenology
Physiology
Carbon use efficiency, plant respiration
Leaf, root, wood - carbon allocation
Background Mortality
Fire
Land cover change

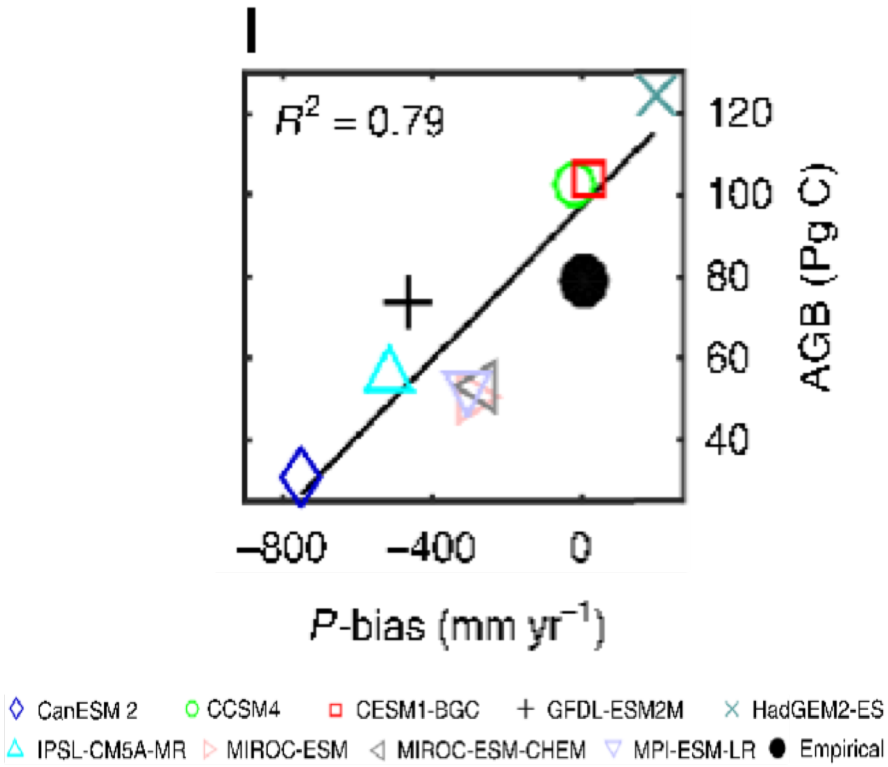
Processes not included in ESMs
Reproduction
Demography/Species composition
Nutrient availability
Forestry
Degradation
Insects, pathogens
Large herbivores
Storms
Land use change e. g. fuelwood harvest

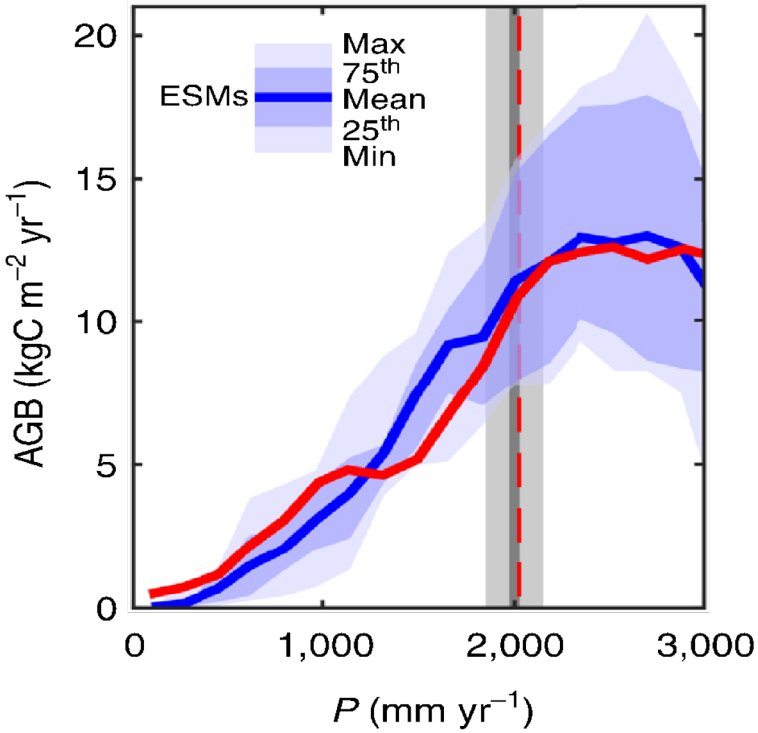
Process oriented model evaluation

ARTICLE
DOI: 10.1038/s41467-017-00306-z OPEN

Hydrologic resilience and Amazon productivity

Anders Ahlström[1,2], Josep G. Canadell[3], Guy Schurgers[4], Minchao Wu[2], Joseph A. Berry[5], Kaiyu Guan[6] & Robert B. Jackson[1,7]





CMIP5 ESM results show that biomass biases are related to climate model biases in the wet tropics, with a contribution from land use at intermediate precipitation

Process oriented model evaluation

- Identify (usually) non modeled factors that control biomass
  - Soil conditions (fertility, water holding properties)
  - Management
  - Diversity / plant traits
  - Subgrid soil moisture and climate variability

Reduction of tree cover in West African woodlands and promotion in semi-arid farmlands

Martin Brandt[1*], Kjeld Rasmussen[1], Pierre Hiernaux[2], Stefanie Herrmann[3], Compton J. Tucker[4], Xiaoye Tong[1], Feng Tian[1], Ole Mertz[1], Laurent Kergoat[2], Cheikh Mbow[5], John L. David[6], Katherine A. Melocik[7], Morgane Dendoncker[8], Caroline Vincke[8] and Rasmus Fensholt[1]

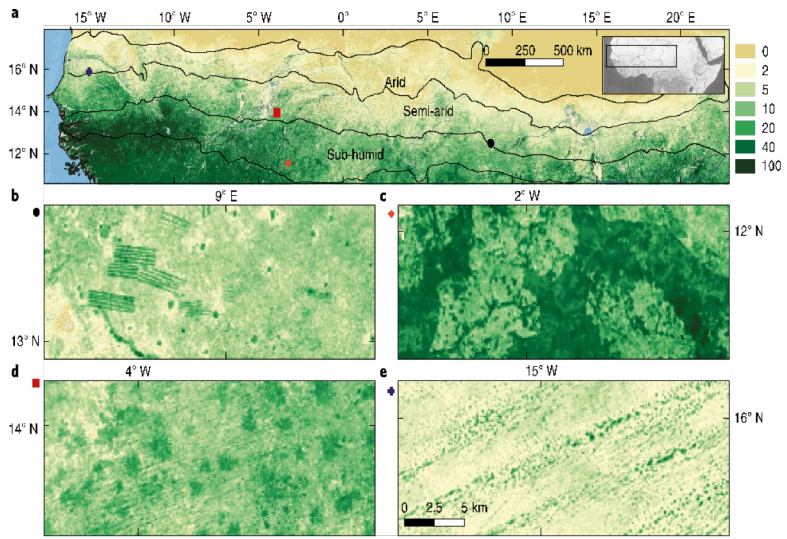


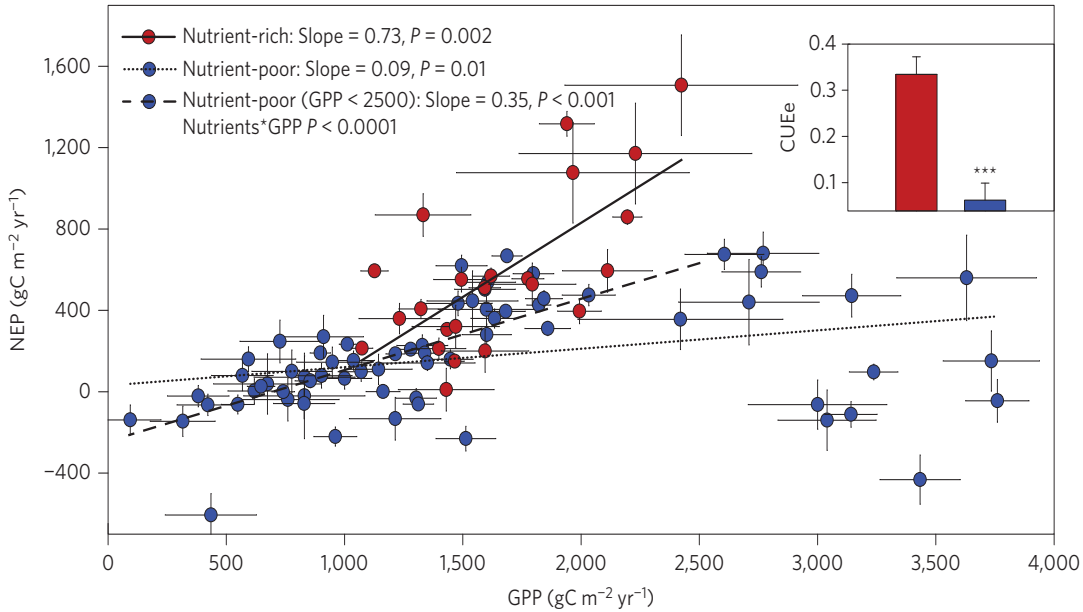
Fig. 2 | Predicting woody cover. a, Predicted woody cover at 100 m resolution with locations of the close-up views (**b**–**e**) indicated. **b**, Woody cover in farmlands at the semi-arid Nigeria/Niger border. The presence of trees within villages makes them stand out as green clusters. Woody corridors (shelterbelts) can be identified. **c**, Farmlands in sub-humid Burkina Faso are expanding into remnants of forest reserves. **d**, The villages in the Malian Seno Plain are surrounded by a well-managed woody vegetation. **e**, The sandy pastoral zone of arid Senegal has locally high concentrations of woody plants on fine-textured soils of inter-dunes.

Process oriented model evaluation

nature climate change
LETTERS
PUBLISHED ONLINE: 6 APRIL 2014 | DOI: 10.1038/NCLIMATE2177

Nutrient availability as the key regulator of global forest carbon balance

M. Fernández-Martínez[1,2]*, S. Vicca[3], I. A. Janssens[3], J. Sardans[1,2], S. Luyssaert[4], M. Campioli[3], F. S. Chapin III[5], P. Ciais[4], Y. Malhi[6], M. Obersteiner[7], D. Papale[8], S. L. Piao[9,10], M. Reichstein[11], F. Rodà[2,12] and J. Peñuelas[1,2]



Emerging constraint

Land-use and land-cover change carbon emissions between 1901 and 2012 constrained by biomass observations

Wei Li[1], Philippe Ciais[1], Shushi Peng[1,2], Chao Yue[1], Yilong Wang[1], Martin Thurner[3], Sassan S. Saatchi[4], Almut Arneth[5], Valerio Avitabile[6], Nuno Carvalhais[7,8], Anna B. Harper[9], Etsushi Kato[10], Charles Koven[11], Yi Y. Liu[12], Julia E.M.S. Nabel[13], Yude Pan[14], Julia Pongratz[13], Benjamin Poulter[15], Thomas A. M. Pugh[5,16], Maurizio Santoro[17], Stephen Sitch[18], Benjamin D. Stocker[19,20], Nicolas Viovy[1], Andy Wiltshire[21], Rasoul Yousefpour[13,‡], Sönke Zaehle[7]

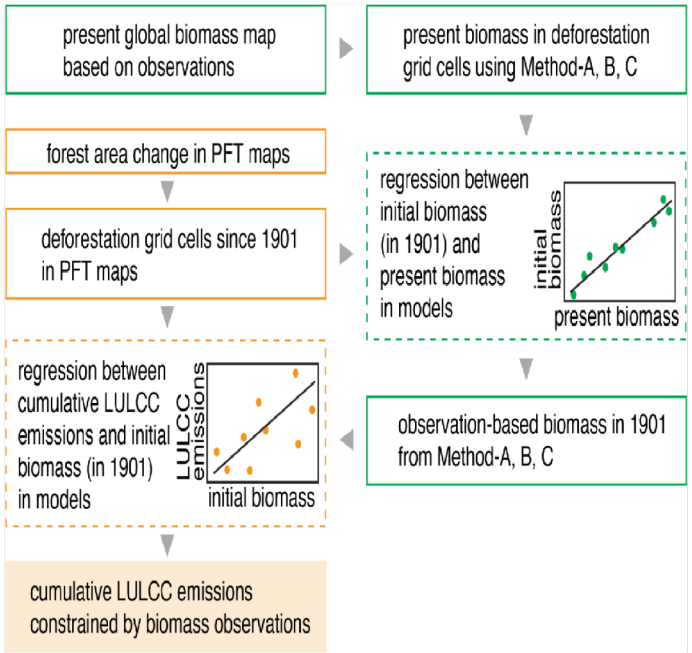
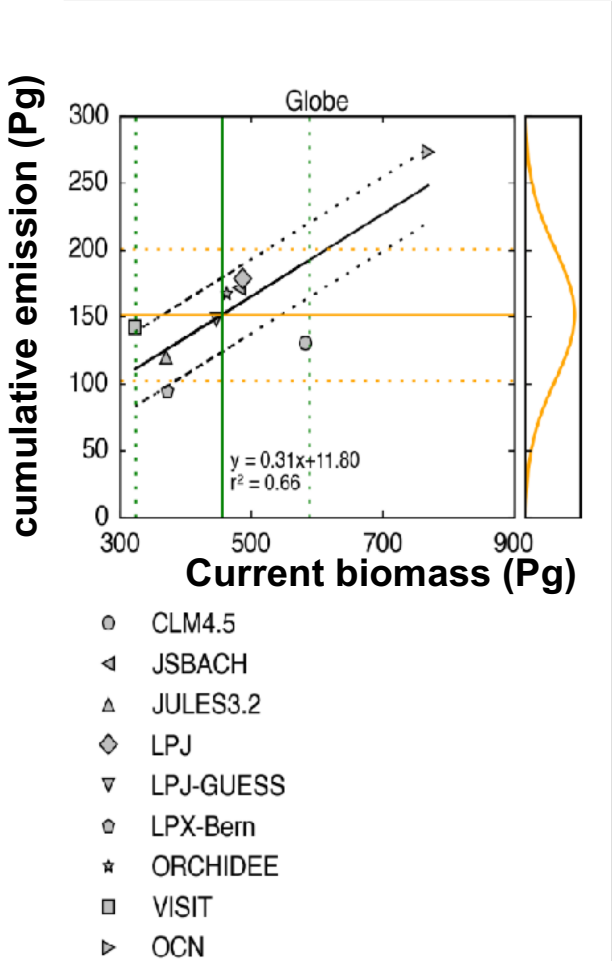


Figure 1. The framework of this study.



To Open the discussion about biomass observation requirement for climate models ?

Current land surface models of ESMs

- Present day biomass
- Pre-industrial biomass
- Split in wood, leaves, roots
- composition (e.g nitrogen,water content)
- Biomass historical change at model grid scale
- If possible annual dynamics
- Total biomass + uncertainty

New generation of land surface models

- Sub-grid statistics of forest structural parameters
- Biomass <u>or</u> height, density, crown area, basal area ?
- Sub-annual dynamics at a spatial resolution sufficient to capture disturbance induced biomass mortality, recovery from drought, effects of management …