Assimilation of forest remote sensing biomass and height data into process-based models: ORCHIDEE in the tropics

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LSCE/EDB

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• Forests regulate biogeochemical cycles (at global scale)
  e.g. carbon sequestration: 1/3 of anthropogenic \( \text{CO}_2 \) emission (Le Quere et al., 2017)

• Signs of forest carbon sink weakening (Nabuurs et al., 2013, Brienen et al., 2015) in response to global anthropogenic disturbances
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Brienen et al., 2015
312 undisturbed plots
(Amazon forest)

• Potential biophysical & biochemical feedback on climate
  eg. Amazon dieback (Cox et al., 2000)
Tools to monitor forest ecosystem (Observations and process based models)

Physiology param
e.g. VCMAX, turgor loss point

Field inventory
DBH, specie, tree height

FluxTOWER (GPP, LE)

Remote sensing
Canopy height, AGB, LAI,
Tools to monitor forest ecosystem (Observations and process based models)

- **Stochastic individual based models**
  - e.g. TROLL, FORMIND

- **Cohorts based models**
  - e.g. ORCHIDEE-CAN, FATES

- **“Big Leaf” land surface models**
  - e.g. ORCHIDEE, CLM

Benchmarking
Parameterization
Initialization
Tools to monitor forest ecosystem (Observations and process based models)

Stochastic individual based models
e.g. TROLL, FORMIND

Cohorts
e.g. ORCHIDEE-CAN, FATES

“Big Leaf” land surface model
e.g. ORCHIDEE-TRUNK, CLM
ORCHIDEE:
- exchange Carbon $\text{H}_2\text{O}$ & energy between atmosphere and surface
- multi-scale model (1 pixel to global)
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- exchange Carbon H$_2$O & energy between atmosphere and surface
- multi-scale model (1 pixel to global) – can be ONLINE (feedbacks)
- several versions
Big-leaf approach (*Krinner et al., 2005*)

Explicit demography represented by downscaling stand level NPP to mean individual (cohort) following the allocation rules of *Deleuze et al. (2004)* Recruitment scheme and self-thinning (*Belassen et al., 2010, 2011; Naudts et al., 2015*)
New generation DGVM – forest structure – open new possibilities to combine OBS and Models examples of using field inventory and remotely sensed data into ORCHIDEE-CAN
Allometric Height-Diameter calibration data from Afrisar & Tropisar

Tree Height = A*Diameter^b

Linear fit used in for CAN configuration set up
**Allometric Height-Diameter calibration** data from Afrisar & Tropisar

Tree Height = A*Diameter\(^b\)

<table>
<thead>
<tr>
<th>Sites</th>
<th>CODE</th>
<th>H/D allometric equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOP</td>
<td>LOP</td>
<td>A(m) 44.148, b0.550, Nbtrees 499</td>
</tr>
<tr>
<td>MABOUINE</td>
<td>MAB</td>
<td>A(m) 41.767, b0.531, Nbtrees 592</td>
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<tr>
<td>MONDAH</td>
<td>MON</td>
<td>A(m) 40.671, b0.506, Nbtrees 510</td>
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<tr>
<td>NOURAGUES</td>
<td>NOU</td>
<td>A(m) 46.538, b0.534, Nbtrees 3154</td>
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<tr>
<td>PARACOU</td>
<td>PAR</td>
<td>A(m) 44.608, b0.561, Nbtrees 1092</td>
</tr>
<tr>
<td>RABI</td>
<td>RAB</td>
<td>A(m) 38.515, b0.470, Nbtrees 1060</td>
</tr>
</tbody>
</table>

Linear fit used in for CAN configuration set up

Labriere et al., 2018
PSEUDO-OBS: Bayesian modelling to assimilate 30yrs of forest inventory and simulate long term C accumulation (Chave et al in prep)
**BENCHMARKING** (forest structure from field inventory and pseudo obs)

**Forest establishment**

Above Ground Biomass

Basal Area

**Equilibrium state**

a) **height vs. diameter**

b) **diameter distribution**

Joetzjer et al., 2018, Chave et al in prep
APPLICATION Data “assimilation” assuming “perfect model”

95p CANOPY HEIGHT

ORCHIDEE-CAN

Look-up table and census data
APPLICATION Data “assimilation” assuming “perfect model”

95p CANOPY HEIGHT

ORCHIDEE-CAN

Look-up table and census data

Paracou assimilated 50th percentile height (m)
APPLICATION Data “assimilation” assuming “perfect model”

95p CANOPY HEIGHT

ORCHIDEE-CAN

Above Ground Biomass

AGB (tC/ha)

years

REF
TRUNK
CAN
CAN–RS
APPLICATION Data “assimilation” assuming “perfect model”

95p CANOPY HEIGHT

ORCHIDEE-CAN

ORCHIDEE-CAN products (exemples)

AGB

Crown size

Litter

Joetzjer et al., 2017
Method
Relatively fast and easy (Calibration with sparse forest inventory)
Provide Detailed estimates of forest stocks (multiple carbon pools)
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Provide *Detailed* estimates of forest stocks (multiple carbon pools)

Limits: assimilation of PLEAIDES canopy height
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Provide Detailed estimates of forest stocks (multiple carbon pools)

Limits: assimilation of PLEAIDES canopy height

Figure 2. Scatterplot of the 95th percentile canopy height derived from Pleiades versus 95th percentile derived from lidar gridded at 100 m x 100 m at (a) Nouragues and (b) Paracou. Green lines represent the mean and deviation of each product.

New generation of data coming
BIOMASS (CNES-ESA) [Le Toan et al., 2011]; GEDI (NASA) [Stysley et al., 2015]
PERSPECTIVES on how to constrain AGB using RS data

ABG (comp. Mitchard et al., 2014 forest inventory RAINFOR)

TRUNK underestimates AGB (background tree mortality)
CAN overestimates AGB self-thinning parameters (and other) calibrated using sites in the east.

CAN and TRUNK failed to reproduce the observed SE-NW AGB gradient
(as most models, Johnson et al., 2016)
Constant mortality in TRUNK
Little variability in CANs even with forest structure

How can we constrain Carbon Residence Time? (AGB/NPP)
Above ground biomass (key forest feature monitored)

Photosynthesis

- GPP
- NPP
- Leaf & woody productivity
- AGB
- RA
- Mortality

Carbon use efficiency
CUE = NPP/GPP

Carbon allocation

Residence time

Inspired from Mahli et al., 2012
Above ground biomass (key forest feature monitored)

PERSPECTIVES on how to constrain AGB using RS data

Well constrained in models
- trait observations (e.g. Vcmax)
- benchmark (e.g. fluxtower)

As important as photosynthesis quantify ABG and AGB variation
But poorly constrained
Above ground biomass (key forest feature monitored)

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PERSPECTIVES on how to constrain AGB using RS data

Carbon residence time underestimated in Global climate model compared to OBS (Carvalhais et al., 2014)

CRT in model is more sensitive to T than P => C feedbacks in future may be more sensitive to hydrological changes than temperature
PERSPECTIVES on how to constrain AGB using RS data

- **BIOMASS data** => Carbon residence time map (PFT dependent parameter) that we can use as an input in ORCHIDEE using e.g. NPP from FLUXNET (Jung et al. 2017)
  - Spatial gradient of AGB
  - Succession?
  - Disturbance?

- **Model development: mortality processes**