Modeling water availability for trees in tropical forests

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outline

1 background

2 the model

3 results

4 summary/future works

why modelling water availability in tropical forest ?

- ▶ tropical forests are subject to a dry season, incl. Amazon Basin
- ▶ climate modeling scenarios, Hadley center, change in annual soil water content for the late XXIth

- ▶ need for developping soil water availability model for tropical forests

soil water cycle model

- Relative Extractable Water: $REW = \frac{EW}{EW_{MAX}}, \in [0, 1]$

soil water balance model

► $\Delta EW = P - In - Tr - Eu - Dr$

water infiltration

- ▶ soil layers
 - soil = succession of 1cm layers
 - each layer has a θ_{PWP} a θ_{FC} and a % of roots
 - estimates of θ_{PWP} and θ_{FC} in the calibration
- ▶ water dynamics
 - water > field capacity in a layer $\implies$ water fills the next layers
 - water remains after the last layer $\implies$ lost by deep drainage

▶ REW

$$\bullet \text{ } REW_d = \sum_{l=1}^{N_{layer}} \underbrace{\left(\frac{\widehat{EW}_{l,d} - \theta_{PWP,l}}{\theta_{FC,l} - \theta_{PWP,l}} \right)}_{REW_{layer}} \times \underbrace{Rfd_l / \sum_{l=1}^{N_{layer}} Rfd_l}_{\text{layer roots \%}}$$

tree transpiration

► computation

► tree transpiration extraction

- fine root density (Rfd) $\implies$ exponential function
- $Rfd(depth) = \lambda_{Rfd} \times \exp(-\lambda_{Rfd} \times depth)$
- $Rfd_I = \int_{depth_{I-1}}^{depth_I} Rfd(depth) ddepth$
- $Tr_{I,d} = \rho_I \times PET \times (1 - \exp(-\lambda_{Rfd} \times N_{layer})) \times Rfd_I$

calibration data

- ▶ site : Paracou experimental site, French Guiana
- ▶ meteorological data : Guyaflux, flux tower, since 2003

calibration data

- ▶ soil moisture measurement : 10 tubes on 4 soil types, TDR probe measurements from 20 to 260 cm by 20, since 2004
- ▶ automatic stem growth measurements: 6 dominant trees

model parameters and inference

► nested structure of the model

model parameters and inference

- ▶ stochasticity of the model : normal error of the probe
- ▶ likelihood of the model

$$\begin{aligned}
 \mathcal{L}(\text{Data}|\Theta_m) &= \prod_{p=1}^{N_{tube}} \mathcal{L}(\text{Data}_p|\Theta_m) \\
 &= \prod_{p=1}^{N_{tube}} \prod_{d=1}^{N_{day}} \prod_{l=1}^{N_{layer}} \frac{\exp \left[- \frac{(\widehat{EW}_{l,d}^p - EW_{l,d}^p)^2}{2(0.2 \times EW_{l,d}^p)^2} \right]}{\sqrt{2\pi(0.2 \times EW_{l,d}^p)}}
 \end{aligned}$$

- ▶ $\widehat{EW}_{l,d}^p$ are the predicted extractable water values

Metropolis-Hastings within a Gibbs algorithm

generation of a candidate θ_k^* and the new vector of parameters $\Theta^*_{:j}$

$$\begin{aligned}\theta_k^* &\sim \pi_{\theta}^{prop}(\theta_k^{n-1}) \\ \Theta^* &= \left\{ \theta_1^{n-1}, \dots, \theta_{k-1}^{n-1}, \theta_k^*, \theta_{k+1}^{n-1}, \dots, \theta_{N_{par}}^{n-1} \right\}\end{aligned}$$

acceptation or rejection of the new candidate θ_k^* by computing the ratio of the likelihood :

$$\gamma = \underbrace{\frac{\mathcal{L}(\text{Data}|\Theta^*)}{\mathcal{L}(\text{Data}|\Theta^{n-1})}}_{\text{likelihood}} \times \underbrace{\frac{\pi_0(\theta_k^*)}{\pi_0(\theta_k^{n-1})}}_{\text{prior}} \times \underbrace{\frac{\pi_{\theta}^{prop}(\theta_k^{n-1}|\theta_k^*)}{\pi_{\theta}^{prop}(\theta_k^*|\theta_k^{n-1})}}_{\text{proposal}} \wedge 1$$

the candidate θ_k^* is accepted or rejected as follows :

$$u^t \sim \mathcal{U}_{[0,1]}, \quad \theta_k^n \begin{cases} \theta_k^* & \text{if } \gamma \geq u^t \\ \theta_k^{n-1} & \text{if } \gamma < u^t \end{cases}$$

model predictions: soil water content

model predictions: REW, relative extractable water

REW and tree growth

► summary

- 1 the method achieve to reproduce the daily extractable water
- 2 new method to estimate field capacity and permanent wilting point
- 3 new method to model roots functioning in soil water balance model

► perspectives

- 1 history of the soil water availability
- 2 linking REW to long-term follow up of tropical forest dynamics
- 3 REW 0.4 threshold for tropical forest species