Model optimization with the 5PM model

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1. Why this model, while there are so many already?
   - Simple and fast
   - 5PM = 5 Parameter Model
   - Flexible time steps
   - Fast for optimization and Monte Carlo simulations

2. Some routines/processes added for LBA-MIP
   - Previously focus on photosynthesis and transpiration relations
   - Comparison with other models
   - Influence of soil moisture
Model overview

1. Estimate respiration from nighttime NEE
   • Radiation to determine nighttime
   • Temperature
   • Optimization of the Lloyd & Taylor (1994) model, $R_{ref}$ and $E_0$ parameters

2. Use GPP and LE to optimize the photosynthesis and transpiration (next slide)

3. Soil water can be limiting GPP and LE
Optimizing the Photosynthesis and Transpiration Model

1. Optimize transpiration (E) and photosynthesis (A):

   • \( C_i = f(vpd, C_s, WUE) \)  
     \(^{\text{(Cowan, 1977)}}\)
   • \( A = f(C_i, \text{PAR}, T, V_{cm}, LUE) \)  
     \(^{\text{(Farquhar et al., 1980)}}\)
   • \( g = A/(C_s-C_i) \)
   • \( E = f(g, vpd) \)

2. Optimize E and A:

   • \text{\textcolor{green}{WUE} in equations above plus} 

3. Iterate step 1 and 2 till parameter values converge
Seasonality in European carbon fluxes

Weekly average showed

Fluxes partitioned with Lloyd & Taylor model, with weekly parameter timesteps
Seasonal variation in Europe improved model results
Input data Manaus K34

Daily average showed

Model time step is one hour
\[\text{NEE} = \text{GPP} + \text{Re} \quad \text{(Manaus)}\]

**Annual \(R_{\text{ref}}\)**
- 1999: 2.53
- 2000: 1.61
- 2001: 2.14
- 2002: 1.30

**Weekly \(R_{\text{ref}}\)**

\[E_0 = 450 \text{ K}\]
Difference between wet and dry season

Dry season doy 152 until 273 (June - September):

\[ R_{ref} = 1.54 \pm 0.38 \]

Wet season:

\[ R_{ref} = 1.64 \pm 0.23 \]
Observed soil respiration and simulated Re

Measurements with Licor 8100 by F. B. Zanchi at K34

Annual parameters
Hourly photosynthesis and transpiration (Manaus)

With annual parameters
\[ r^2(A) = 0.75 \]
\[ r^2(E) = 0.86 \]

With weekly parameters
\[ r^2(A) = 0.70 \]
\[ r^2(E) = 0.89 \]

Example: Hainich
\[ r^2(A) = 0.65 \rightarrow 0.89 \]
\[ r^2(E) = 0.71 \rightarrow 0.81 \]
Daily average fluxes

Observations
Simulations
With annual parameters
## Weekly parameters

<table>
<thead>
<tr>
<th>Year</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>$V_{\text{cm opt}}$ (µmol m$^{-2}$ s$^{-1}$)</td>
<td>176</td>
</tr>
<tr>
<td>2000</td>
<td>$V_{\text{cm opt}}$ (µmol m$^{-2}$ s$^{-1}$)</td>
<td>143</td>
</tr>
<tr>
<td>2002</td>
<td>$V_{\text{cm opt}}$ (µmol m$^{-2}$ s$^{-1}$)</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>LUE (leaf area index)</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>LUE (leaf area index)</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>LUE (leaf area index)</td>
<td>0.35</td>
</tr>
<tr>
<td>1999</td>
<td>WUE (mol mol$^{-1}$)</td>
<td>161</td>
</tr>
<tr>
<td>2000</td>
<td>WUE (mol mol$^{-1}$)</td>
<td>258</td>
</tr>
<tr>
<td>2002</td>
<td>WUE (mol mol$^{-1}$)</td>
<td>291</td>
</tr>
</tbody>
</table>
Dry season doy 152 until 273 (June - September):

- $V_{\text{cm,opt}} = 160.0 \pm 39.3$
- $\text{LUE} = 0.32 \pm 0.09$
- $\text{WUE} = 295 \pm 81$

Wet season:

- $V_{\text{cm,opt}} = 146.2 \pm 46.6$
- $\text{LUE} = 0.45 \pm 0.10$
- $\text{WUE} = 306 \pm 155$
5PM (5 Parameter Model)

1. Radiation balance
2. Ecosystem respiration
3. Potential photosynthesis and transpiration (atmospheric demand)
4. Vegetation interception
5. Soil moisture, infiltration, soil evaporation, root uptake, drainage
6. Actual photosynthesis and transpiration (soil water limited)
7. Sensible heat and vegetation temperature
Air temperature

Weekly average
Interannual variation
Vapour pressure deficit

Weekly average
Interannual variation
Model parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial</th>
<th>After optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_0$</td>
<td>200</td>
<td>450 K</td>
</tr>
<tr>
<td>$R_{\text{ref}}$</td>
<td>2.0</td>
<td>1.9 µmol m$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>$V_{\text{cm, opt}}$</td>
<td>50</td>
<td>148 µmol m$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>LUE</td>
<td>0.40</td>
<td>0.43</td>
</tr>
<tr>
<td>WUE</td>
<td>1000</td>
<td>237 mol mol$^{-1}$</td>
</tr>
</tbody>
</table>

No clear seasonality of the parameters found
Constant values used for all sites
$$\text{NEE} = \text{GPP} + \text{Re}$$

After optimization, limitation by soil water is visible and very sensitive to parameters.
First calculations

After optimization

Not very sensitive to parameters
Soil wetness

First calculations

After optimization
How to go to regional parameters

- Optimized parameters of Manaus are most likely not valid at other sites
- Try to derive parameters for all 8 sites
- Look for relations between parameters and environment (climate, soil, vegetation…) across sites
- Use these relations to scale to whole region
Conclusions

• Model parameters do not show seasonality for K34 tower. Single values can be used.
• Seasonality is simulated by soil water limitations
• Respiration is process most difficult to model, with largest uncertainties
• Carbon fluxes are more sensitive to model parameters than water fluxes
• Method can be useful to define regional parameters
Acknowledgements

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- Santarem K77: Fitzjarrald, Moraes
- Santarem K83: Goulden, Miller, Rocha
- Reserva Jaru: Cardoso, Manzi
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- Reserva Pe de Gigante: Rocha