Impact of Mesophyll Diffusion on Estimated Global Terrestrial Transpiration and Water Use Efficiency

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Mesophyll diffusion:
A strong barrier for CO$_2$ availability for photosynthesis

Mesophyll and stomatal conductances have similar magnitudes

Mesophyll diffusion of CO$_2$ ($g_m$):
*Intercellular air space* to the *interior of chloroplast*

Stomatal diffusion of CO$_2$ ($g_s$):
*Atmosphere* to *Intercellular air space*
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The first global mesophyll conductance model

\[ g_m = g_{\text{max}} \cdot f_T(T) \cdot f_w(\theta) \]

- **Leaf-level parameterization**
- **Scaling up to canopy level**
  - **Sunlit leaf**
  - **Shaded leaf**
  - **Vertical gradient**
- **Conversion of photosynthetic parameters**

- Ignoring mesophyll diffusion leads to underestimation of CO₂ fertilization effect.

The contemporary biosphere is more CO₂ limited than previously thought.

(Sun et al. 2014)
Water Use Efficiency (WUE):

A critical index bridging water cycle and carbon cycle

WUE has different definitions

\[
WUE = \frac{\text{Rate of Carbon Assimilation}}{\text{Rate of Transpiration}} = \frac{A}{E}
\]
Question:

How does mesophyll diffusion affect simulated WUE?

\[ A = g_m (C_i - C_c) = \frac{g_s \cdot g_m}{g_s + g_m} (C_a - C_c) \]

\[ WUE = \frac{A}{E} \]
Simulation Design

- **CLM4.5**
  - CTRL - Control run
  - MESO - Simulation with fully updated mesophyll conductance model and recalibrated biochemical parameters of photosynthesis

- **Time**
  - 1901-2010

- **Resolution**
  - $1.9^\circ \times 2.5^\circ$ (lat $\times$ lon)
Without gm, CLM estimated WUE but underestimated long-term trend. Without gm, CLM underestimated ET.
Without gm, CLM underestimated long-term trend
Conclusions

1. Inclusion of mesophyll diffusion in the model results in generally higher simulated transpiration.

2. The long-term trend of increase in WUE due to anthropogenic CO$_2$ emission is underestimated if mesophyll diffusion is not considered.

3. Models might achieve temporary accuracy through parameters tuning but better process representation is required to reliably predict long-term trends.
Thank you for your attention!

Suggestions & Comments are welcomed!

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