Improving representation of radiation interception and canopy photosynthesis within JULES

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JULES launch
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Why are we looking at radiation interception and carbon uptake within JULES?

Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model

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Radiation interception: old vs new approach

Beer’s law
\[ I = I_0 \cdot e^{-k \cdot LAI} \]
No scattering: i.e. sum of reflected and transmitted light

Two stream approximation (Suits, 1972; Sellers, 1995):
Vertical profiles:
upward and downward diffusive radiative fluxes

Takes into account:
- Leaf and soil scattering
- LAI and Leaf angle distribution
- Angle of incident radiation
- Diffuse and direct radiation
Canopy photosynthesis: old vs new approach

**Big leaf**
- 1 single layer
- Photosynthesis: Proportional to average absorbed irradiance
  \[ \Sigma \text{leaf capacities} \]

**Multilayer**
- \[ \Sigma \text{photosynthesis at each layer} \]
- VERTICAL variations in light (homogeneous)
- variations in parameters \[ N = f(V_{\text{max}}) \]
- canopy microclimate (T, VPD)

**Standard JULES**

\[ V_{\text{max}} = K \]

\[ V_{\text{max}} \neq K \]
Model evaluation: rainforest site

\[ A_n = \text{net carbon uptake} = \text{Total photosynthesis (GPP)} - \text{leaf respiration} \]

**Big leaf model**
\[ y = 0.85x \quad r^2 = 0.89 \]

**Multilayer**
\[ V_{\text{max}} = K \]
\[ y = 0.83x \quad r^2 = 0.92 \]
\[ V_{\text{max}} \neq k \]
\[ y = 0.86x \quad r^2 = 0.93 \]
Further Analysis: rainforest site

Possible reasons for remaining discrepancy

- $A_n$ data (NEE + ecosystem respiration) is too high:
  ecosystem respiration (soil $CO_2$ efflux)

- Model $A_n$ is too low:
  
  model parameters: increase $V_{\text{max}}$
  model process: decrease leaf respiration due to light inhibition (Brooks & Farquhar 1985)

$V_{\text{max}}$= 18% higher (42-50 $\mu$mol m$^{-2}$ s$^{-1}$)
$y = 0.96x$  $r^2 = 0.92$

Inhibition of leaf respiration by light
$y = 0.96x$  $r^2 = 0.93$
Initial results from global implementation

Comparison of $\text{GPP}$ and $\text{NPP} = \text{GPP} - \text{Plant Respiration}$

big leaf (BL) & multilayer (ML) approach ($v_{\text{max}} = k$)

Mean June from 1986-1995

$\text{GPP (ML)} - \text{GPP (BL)}$

$\text{NPP (ML)} - \text{NPP (BL)}$

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Conclusion

- Jules with multilayer gives improved results to big leaf

- Jules is able to represent the observations

- Initial global simulations indicate main differences in GPP using multilayer approach in the tropics
Further work

Further improvements are obtained for the tropical site
- Increasing $V_{\text{max}}$ or
- Including inhibition of leaf respiration by light

Initial global simulations indicate
a reduction of tropical NPP with multilayer
approach

Current work
Implementation of varying N with canopy depth
Implementation of inhibition of leaf respiration by light

Outlook
- Validation of global model (GPP)
- Tool to simulate effects of diffuse irradiance on GPP