Effects of nitrogen limitation on hydrological processes in CLM4-CN

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Carbon-Nitrogen-Water coupling through leaf’s stomata

CO₂

Internal leaf CO₂ ($c_i$)

Leaf surface CO₂ ($c_s$)

Photosynthesis

Stomatal conductance ($g_s$)

N-limitation

Water stress

Transpiration

Runoff

Ball-Berry Model

(Ball et al., 1987)

$$g_s = k \frac{A h_s}{c_s}$$

$g_s$: Stomatal conductance  
$k$: Slope constant of the model  
$A$: CO₂ assimilation rate  
$h_s$: Relative humidity  
$c_s$: CO₂ concentration at the leaf surface

$GPP$: Gross Primary Productivity
We examine the effects of CO$_2$ and nitrogen limitation on carbon-nitrogen-water coupling in leaf’s stomata and thereby hydrological processes using the Community Land Model with coupled Carbon and Nitrogen cycles (CLM4-CN).
Experimental designs

CESM 1.0.1 CLM 4.0 with coupled carbon and nitrogen (CN): Stand-alone CLM with Qian atmospheric input data for 1948-1972 and transient CN, aerosol deposition from 1850-2000 and 2000 CO$_2$ level (I_1850-2000_CN)

Initial model experiments  $I_{1850}$CN (700-yr equilibrium run)
Pre-industrial stand-alone CLM-CN using a reference case

Three sensitivity experiments (151-yr transient runs: 1850-2000)
1. Control (I8520CN)
2. Nitrogen limitation (I8520CN-downregulation)
3. Constant CO$_2$ (I8520CN-constant)
Approach: downregulation experiment

The stomatal resistance is not linked to the down-regulated GPP by nitrogen limitation.

- Total gross photosynthesis (GPP) in CNAllocationMod is coming from CanopyFluxesMod, then it’s scaled by nitrogen limitation.
- The photosynthesis used to control stomatal conductance in current CLM4-CN is not affected by nitrogen limitation.

- We scale “foliage photosynthesis ($psn$)” in stomata subroutine by “fractional reduction in GPP due to nitrogen limitation ($downreg$)” in CNAllocation module from the previous time step.
Photosynthesis used in Ball-Berry is lower in the downregulation run.
Nitrogen limitation effects: transpiration and total ET

Canopy transpiration ($q_{\text{veg}}$)

Total evapotranspiration ($q_{\text{veg}}+q_{\text{vege}}+q_{\text{soil}}$)
Nitrogen limitation effects: runoff and soil water

Total liquid runoff (qrunoff)

Volumetric soil water (h2osoi)
Nitrogen limitation effects: GPP

Downregulation – Control

gC/m²/yr
Conclusions

• Nitrogen limitation in stomata affects hydrological processes through changes in photosynthesis.

Decreasing canopy transpiration and total evapotranspiration Increasing runoff and soil water

➢ Decreasing ET and increasing runoff due to nitrogen limitation might improve simulating ET and runoff, which are too high (ET) and too low (runoff) in current CLM4-CN (Lawrence et al., 2011).
Next steps…

• Running stand-alone CLM with “transient historical CO$_2$ concentration”

• Constant CO$_2$ experiments one for internal CO$_2$ ($c_i$) and another for leaf surface CO$_2$ ($c_s$): positive and negative feedback in carbon and water coupling

• Statistical significance test for the differences

• Evaluating model outputs with observations
  Gridded dataset (EC-MOD data; Xiao et al., 2011) from eddy flux and MODIS data
  Site-level data from flux tower measurements

➢ Is there an improvement in simulating diurnal and seasonal cycles of GPP?
Questions and comments