River N Export: a Constraint on Mineral N Loss in the CLM-CN?

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Global Reactive Nitrogen (Nr) Creation by Human Activity 1850 to 2005

\[ \text{N}_2 + 3\text{H}_2 = 2\text{NH}_3 \]

Total Nr Creation, Tg N yr\(^{-1}\)

- Haber Bosch
- Legumes
- Fossil Fuel

Population, billions

Nr Creation, Tg N yr\(^{-1}\)

1850 1875 1900 1925 1950 1975 2000 2025 2050

0 50 100 150 200 250

Courtesy of J. Galloway
Atm CO₂

Plant

Litter

Soil Organic Matter

Carbon cycle

Respiration

Atm CO₂ → Plant → Litter → Soil Organic Matter

Nitrogen cycle

Atm N₂O → Atm N₂

Inorganic Soil N

0.1-0.2% Nitrification

0.2-5% Denitrification

Atmospheric N Deposition

Biological N₂ Fixation

Leaching (0.01 Tg N/yr)

Adapted from Thornton et al., 2009
Too Much Nitrogen: A “Cascade” of Consequences

- Smog, Haze
- Forest Die-back
- Acidification
- Ozone Depletion
- Global Warming
- Eutrophication

Courtesy of J. Galloway
Does it matter whether or not CLM-CN correctly partitions mineral N losses between denitrification and leaching?

Yes, if you want to capture the full nitrogen “cascade.”

How will we know if revised versions of CLM-CN are getting mineral N losses right?

Compare results directly to observed leaching or denitrification rates.

Compare to global patterns of river N export.
Simulating Nitrogen Transport in the CLM-River Transport Model (RTM)

Water Fluxes

N Fluxes

\[ \text{totrunin from CLM} \]

\[ \text{sfluxin} \quad \text{volr} \quad \text{fluxout} \]

\[ \text{nleachin from CLM} \]

\[ \text{sediment\_denit} \quad \text{nfluxin} \quad \text{nfluxout} \]

\[ N_\text{tot} \]
N Leaching Flux in CLM-CN
Parameterization of Nitrogen Transport in CLM-River Transport Model (RTM)

Water Fluxes

\[ \text{totrunin from CLM} \]

\[ \text{sfluxin} \quad \text{volr} \quad \text{fluxout} \]

N Fluxes

Use 40\% of soil denitrification flux

\[ \text{N}_{\text{tot}} \]

\[ \text{nfluxin} \quad \text{sed}_{\text{denit}} \quad \text{nfluxout} \]
Mineral N Losses and Inputs in CLM-CN
N River Transport in Coupled RTM/CLM-CN
River N Export to the Ocean

Modeled v. Observed Export

\[ R = 0.87 \]

\[ \text{Slope} = 0.79 \]
River $[N]_{\text{total}}$ Concentration (mg/L)

Modeled v. Observed $[N]_{\text{tot}}$

$R = 0.57$
Slope = 0.32

RTM $[N]_{\text{tot}}$ (mg/L)

Observed $[N]_{\text{tot}}$ (mg/L)
River $[N]_{\text{total}}$ “Natural” Rivers Only

Agricultural + Point Sources < 15% of total N inputs
Lena

Why is RTM overestimating dissolved [N]?
 Changes in $[N]_{\text{tot}}$ along Longest Main Stem of River

Yukon

Amazon

![Graphs showing changes in $[N]_{\text{tot}}$ along the Yukon and Amazon rivers.](Image)
Summary

1) CLM-CN underestimates mineral N losses due to leaching and may tend to downplay the impact of anthropogenic N additions on the Earth System.

2) Total CLM-CN mineral N losses, when input to the RTM (scaled down by 0.4), produce (somewhat) reasonable patterns of global river N export and dissolved [N] concentration.

   a) Global N export underestimated due to lack of agricultural N inputs.

   b) [N] tends to be overestimated in “natural” Arctic rivers.
Mississippi River Seasonality in [N] vs. Water Flow

Observed (USGS NASQAN)  

CLM-RTM
N Inputs and Outputs in CLM-CN
Missouri/Mississippi River

RTM results in Mississippi River Basin showing USGS NASQAN Monitoring Sites

Remove 17 and 13
N Fertilizer Consumption Trends 1961-2009

Data from FAOSTAT
Why is RTM overestimating dissolved [N]?