Land-coastal Ocean Interactions: Insights from the GFDL Land Model

Minjin Lee

Geophysical Fluid Dynamics Laboratory Review

October 29-31, 2019

Linking Land and the Coastal Ocean at GFDL

Empirical global watershed models

- e.g., Global NEWS, etc
- Observed relationships are used to estimate river N loads for only a few reference years and may not be valid in the future experiencing unprecedented anthropogenic land use and climate changes.

Process-based watershed models

- e.g., RHESSys , INCA, SWAT, etc
- Tuning of basin-specific parameters are often required.

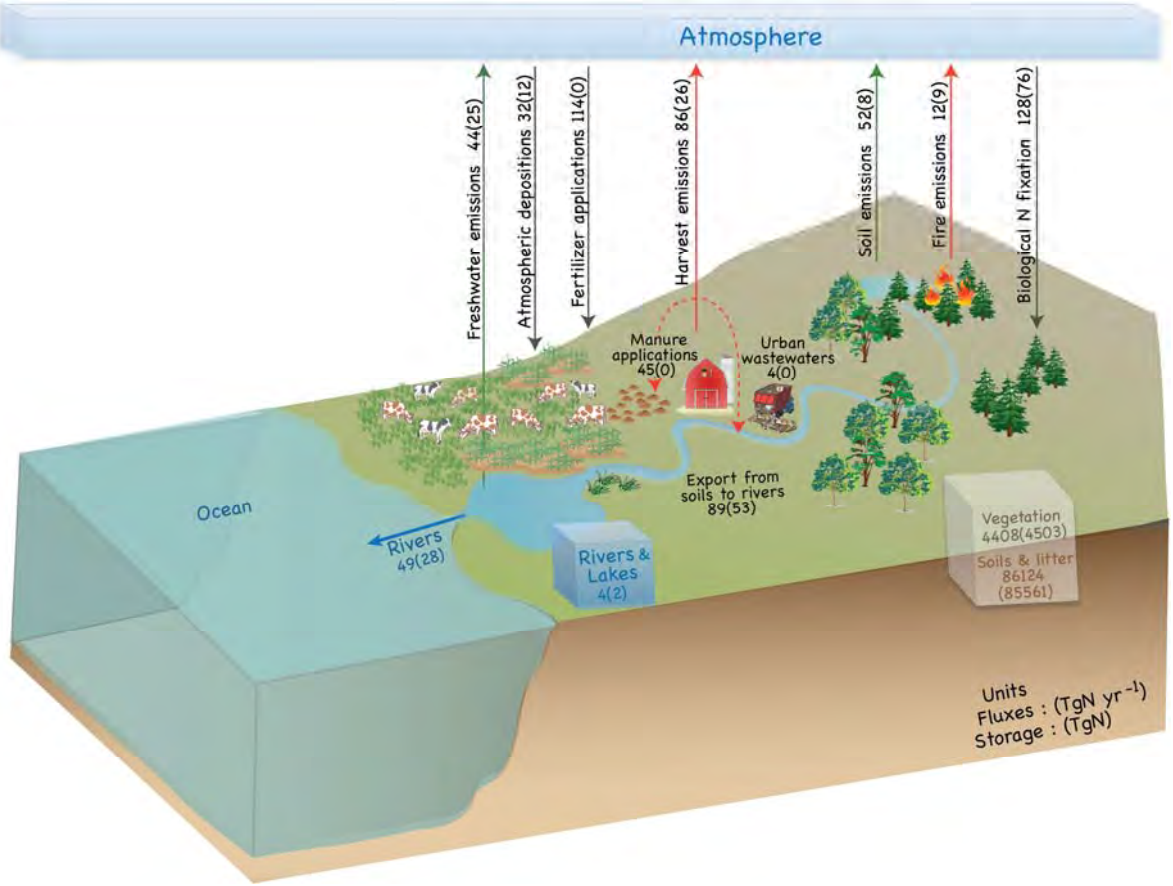
Process-based global Terrestrial Ecosystem Models (TEMs)

- e.g., **GFDL/LM3V-N**, CLM-CN, etc
- Simulations are limited to terrestrial ecosystems.

Process-based TEMs + global river routing and biogeochemistry
e.g., **GFDL/LM3-TAN**, CLM-RTM, etc

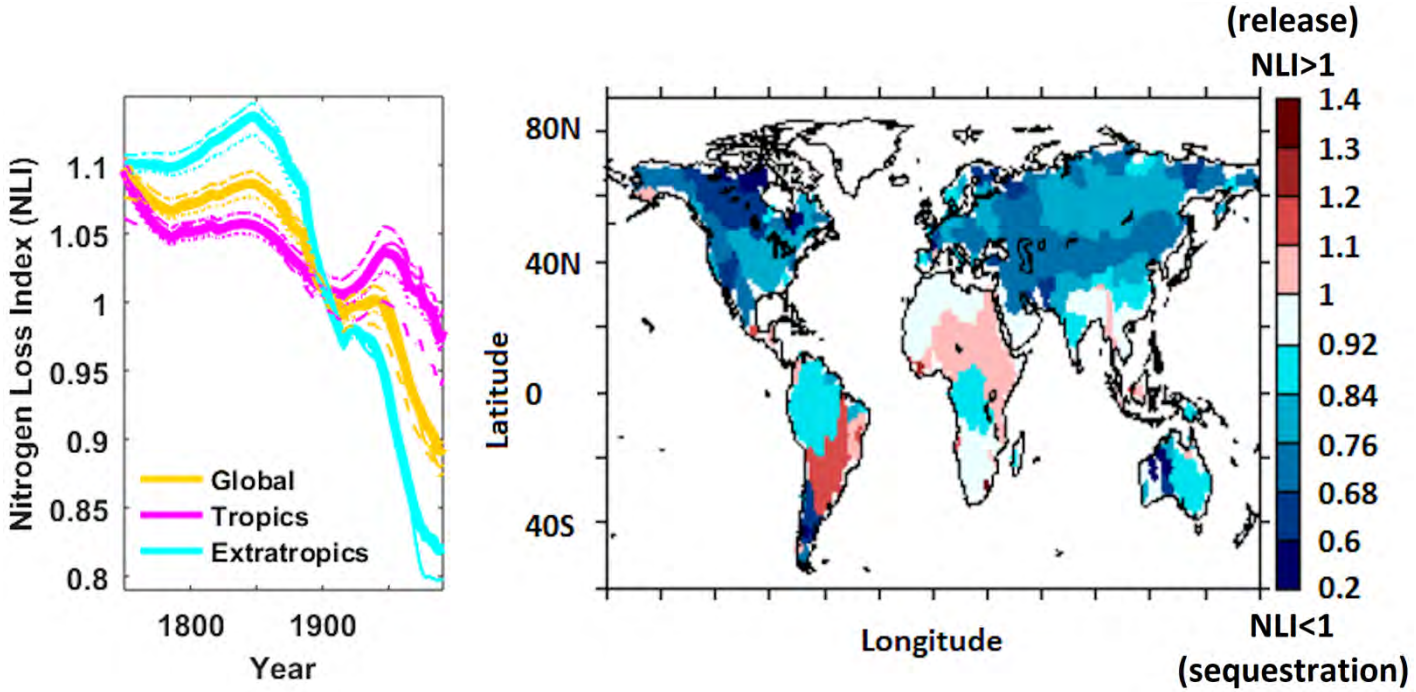
GFDL Land Model LM3-TAN Framework

- Soil-plant C and N cycles [Shevliakova et al., Global Biogechem Cy, 2009; Gerber et al., Global Biogechem Cy, 2010]
- Hydrology and river routing [Milly et al., J Hydrometeorol, 2014]
- Freshwater N cycle [Lee et al., Biogeosciences, 2014]



Prominence of the Tropics in the Recent Rise of Global N Pollution

N Loss Index (NLI): total N outputs from land, divided by total N inputs to land, with NLI<1 (NLI>1) indicating land N sequestration (release)

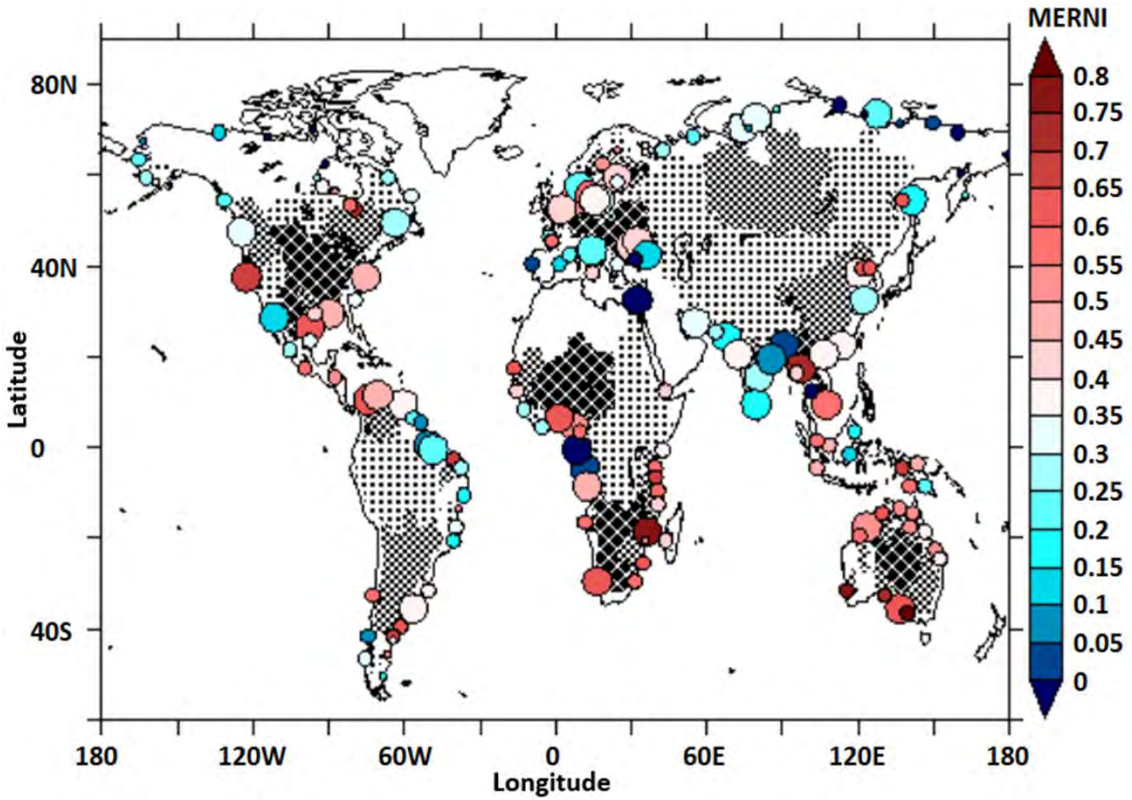


- Many basins in the extratropics are sequestrating N, due to recovery from past land use and land cover change (LULCC).
- Many basins in the tropics are releasing N, due to recent accelerating LULCC.
- The tropics are producing 56 ± 6% of global land N pollution to the ocean and atmosphere.

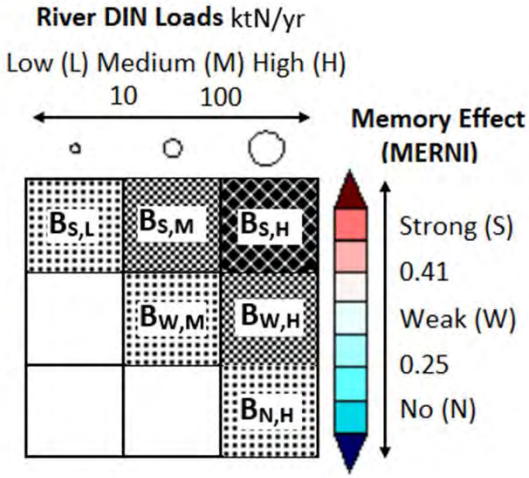
Lee et al., Nat Commun, 2019

Land N Memory Effect on Coastal Eutrophication

- A land N memory effect can significantly amplify extremes of river N loads.
- The effect is prevalent globally and varies widely in strength across the globe.
- Strong effects can produce 25 (4-79)% higher N loads than would otherwise be expected from simple scaling between river discharges and N loads.



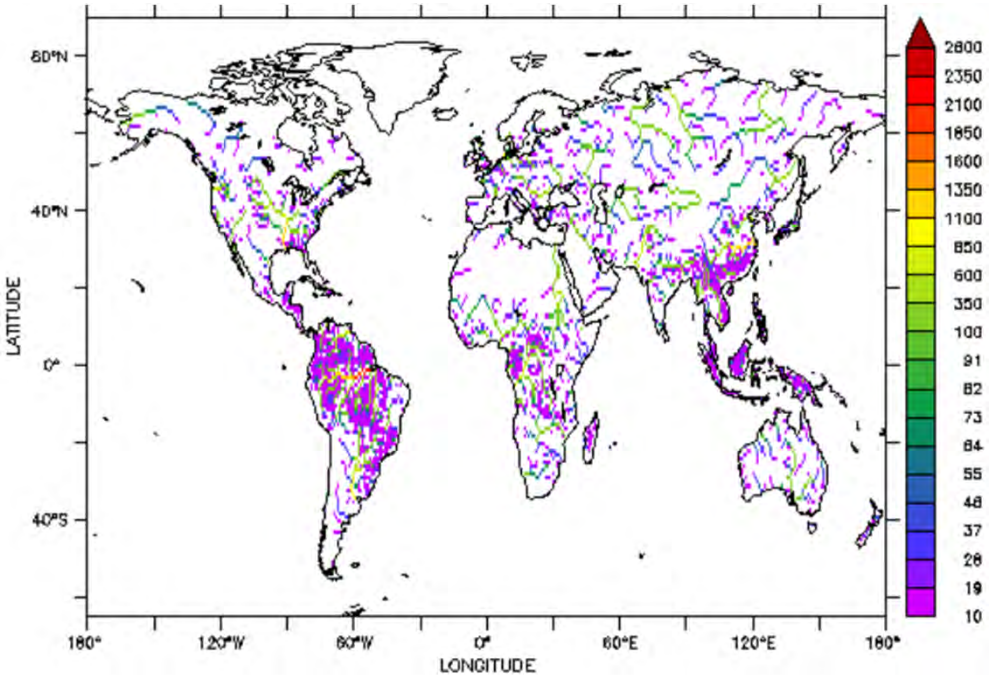
Memory-Effect-on-River-N Index (**MERNI**), with a larger MERNI indicating a stronger memory effect



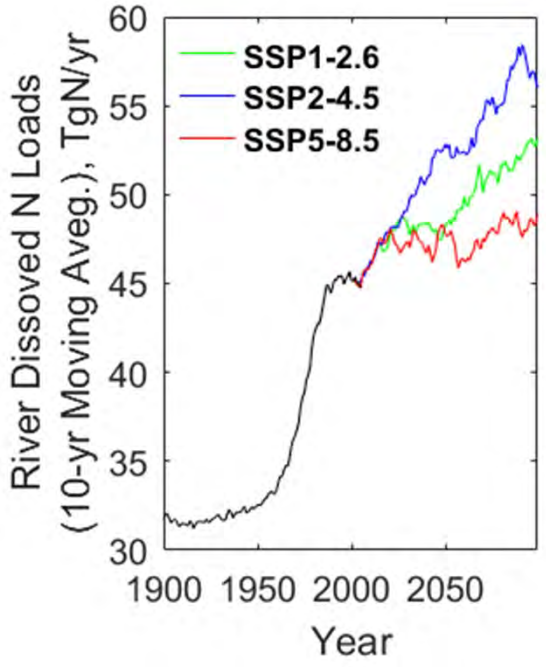
Lee et al., GRL, 2016; Lee et al., In Prep

Advanced Dataset of Long-term Dynamic Global River N Loads to the Coastal Ocean (1700-2100)

River DN loads for the year 1995 (ktN/yr)



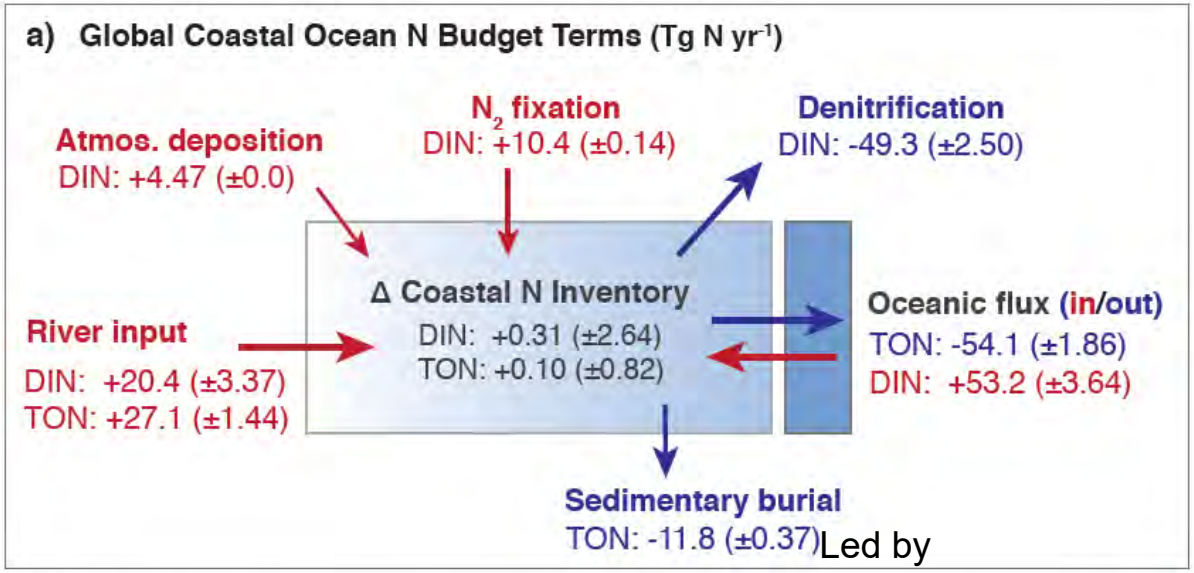
Increases in future river N loads under land use and emission scenarios based on the shared socioeconomic pathways

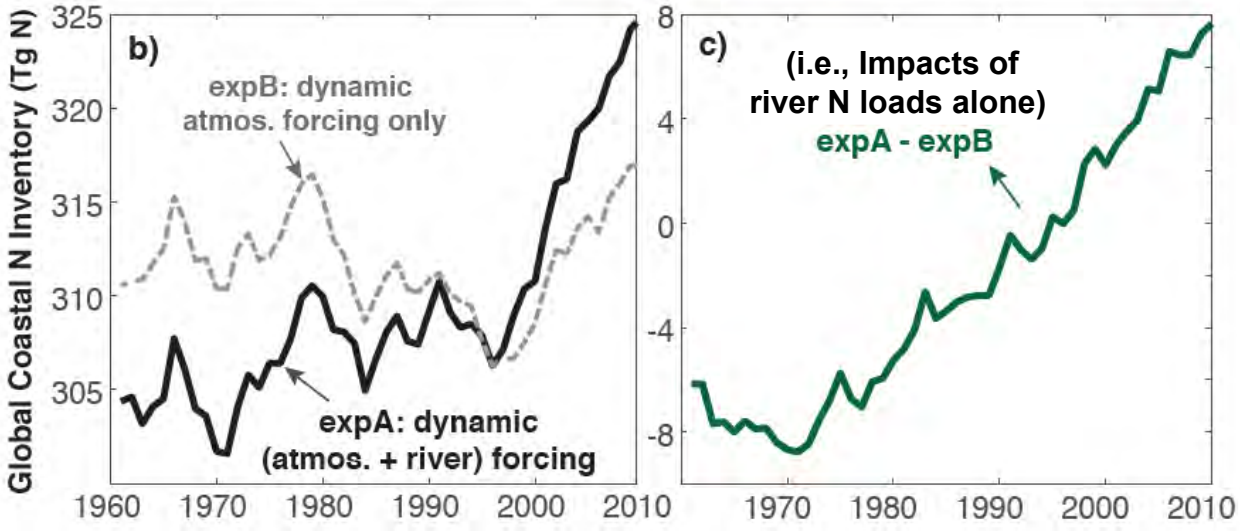


A global implementation of LM3-TAN provides an advanced dataset of long-term (1700-2100) dynamic global river N inputs for ocean biogeochemistry models, most of which currently rely on prescribed data for a few reference years.

Lee et al., Nat Commun, 2019; Lee et al., In Prep

Increases in Global Coastal N Inventory





- Coastal N inventory is indicative of coastal eutrophication.
- The global coastal N inventory increased substantially over the past 50 years largely due to enhanced river N loads.

Led by Princeton/GFDL Postdoctoral Researcher Xiao Liu

Liu et al., In Prep

Summary & Future Plans

Summary

The GFDL Land model LM3-TAN has **an advanced framework that fully couples the terrestrial ecosystem model with global river routing and biogeochemistry**. This allows to

- ✓ estimate global land N pollution to the ocean and atmosphere,
- ✓ investigate the role of interactions between land N storage and climate variability in producing water-pollution extremes, and
- ✓ identify the dominant driver of increases in global coastal eutrophication.

These efforts support **NOAA's missions to understand, anticipate, and reduce the impacts of climate change and weather extremes on coastal ecosystems and resources**.

Future Plans & Challenges

- Additional regional applications (e.g., Great Lakes, in corporation with NOAA/GLERL)
- Development of a comprehensive freshwater biogeochemistry model of coupled carbon, nutrient, sediment, and algal dynamics
- Integration of the freshwater biogeochemistry model with LM4 and evaluation of the integrated model's freshwater-soil-plant biogeochemical simulations
- Linking atmospheric, terrestrial, freshwater, and ocean biogeochemistry as part of GFDL Earth System Models