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

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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/LM3-V-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 Biogeochem Cy, 2009; Gerber et al., Global Biogeochem 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.
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.
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.
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.

Liu et al., In Prep
Led by Princeton/GFDL Postdoctoral Researcher
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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