Current N Inputs to Terrestrial Systems

~250 Tg N y\(^{-1}\)

- **Biological N\(_2\) Fixation**: 90-130 Tg
- **Combustion of Fossil Fuels**: 21 Tg
- **Synthetic Fertilizer**: 78 Tg
- **N\(_2\) Fixation Rice, Soybeans, Alfalfa**: 43 Tg
- **Lightning**: <3 Tg

Galloway et al., 1995
Integrating Landscapes to Waterscapes

~250 Tg N/y
Land-based N Inputs (BNF, synthetic fertilizer, Atmos. Dep. N)

Terrestrial → Rivers → Estuaries → Ocean Margins → Oceanic
Global NEWS Model

**Nutrient Export from Watersheds**

<table>
<thead>
<tr>
<th>Dissolved</th>
<th>Particulate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inorganic</strong></td>
<td><strong>Organic</strong></td>
</tr>
<tr>
<td>N</td>
<td>DIN</td>
</tr>
<tr>
<td>P</td>
<td>DIP</td>
</tr>
<tr>
<td>C</td>
<td>DOC</td>
</tr>
<tr>
<td>Si</td>
<td></td>
</tr>
</tbody>
</table>

(DSi soon)

12 papers *Global Biogeochemical Cycles*, special section Dec. 2005
Overview

- Global N, P and C river transport from watersheds to coastal systems
  - Approach
  - Magnitude and spatial patterns
  - Drivers

- Effect of land-based nutrient inputs

- Fate of N input

- Atmospheric N deposition to coastal and oceanic systems

- Future directions
NEWS Model

Nutrient Sources

Natural
N₂-Fixation
P Weathering

Anthropogenic
Non-Point
Fertilizer (by crop type)
N₂-fixation - crops
Atmos. Dep. N
Manure
(by animal species)

Point
Sewage
(pop.; treatment level)

Hydrology & Physical Factors

Global Watersheds
Water Runoff
Precip. Intensity
Land-use
Slope

In-River N & P Removal

Rivers & Reservoir
Consumptive
Water Use

>4500 watersheds globally
A Few Model Input Datasets

Runoff

Population Density

Fertilizer P input

Annual
0.5 x 0.5 degree
>4500 watersheds
## River Export

<table>
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<tr>
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( DSi soon)

12 papers *Global Biogeochemical Cycles*, special section Dec. 2005
Comparison of Model Predicted vs Measured River Transport

**ChangJiang vs Rhine**

**Mississippi vs Elbe**

**Yukon vs Kolyma**

**Kamkatcha vs Susquehanna**

**R2=0.79**

**DIN**

**Measured DOC yield**

**Modeled DOC yield**

**R2=0.88**

**Calibration Basins**

**Validation Basins**

**Colorado**

**Huang He**

**Susquehanna**

**Ganges**

**Rhine**

**Gambia**

**Dnepr**
Global Patterns of Export
Yield – kg N or P km$^{-2}$ y$^{-1}$

DIN

DIN
(kg N km$^{-2}$ y$^{-1}$)
0 - 40
40 - 70
70 - 140
140 - 280
280 - 570
570 - 1,220
1,220 - 7,550

Dumont, Harrison, Kroeze, Bakker & Seitzinger  GBC 2005

DIP

DIP
(kg P km$^{-2}$ y$^{-1}$)
0 - 0.5
0.5 - 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 50
50 - 100
100 - 500
500 - 1,153

Harrison, Seitzinger, Bouwman, Caraco, Beusen & Vörösmarty  GBC 2005
Regional Analysis
DIN Export by Rivers

(kg N/km² watershed/yr)

- Ganges/Brahmaputra accounts for 60% of river DIN load to BB
- DIN load to BB+AS accounts for 20% of total global DIN export

494 3,600

Total Export - $10^9$ g DIN/yr
DOC and POC Loads by Latitude

DOC loads, Mton C/yr

75% of TOC enters in tropical latitudes

Totals
DOC 170 Tg
POC 197 Tg
N and P River Export by Form by Latitude

Tg N/yr

60-90N
30-60N
0-30N
0-30S
30-60S
60-90S

Tg P/yr

60-90N
30-60N
0-30N
0-30S
30-60S
60-90S

71% tropics

83% tropics
TN:TP River Export

Mayorga et al. in prep.
N and C River Export by Form by Latitude

Tg N/yr

- 60-90N
- 30-60N
- 0-30N
- 30-60S
- 60-90S

Tg C/yr

- 60-90N
- 30-60N
- 0-30N
- 30-60S
- 60-90S

N x Redfield C:N Ratio = Potential C Production
Amount of OC Delivered Rivers = 2-3x Amount of OC that Could be Produced from DIN Delivered by Rivers
Nutrient Sources and Hydrology

Why might you care about nutrient sources in watersheds and watershed hydrology?

Scenarios for future conditions -

- climate change hydrology
- development scenarios
DIN Export Variation in Dominant Source

From: Dumont, Harrison, Kroeze, Bakker & Seitzinger GBC 2005
From: Dumont et al. 2005 and Harrison et al. GBC 2005
Climate Change effects on water runoff and consumptive water use (irrigation)

Biofuels

Millennium Assessment Scenarios (2025 and 2050)

include social, economic, policy, and ecological considerations
What is the Effect on Continental Shelf Primary Production of:

• N inputs from rivers?

• N removal by denitrification?
Modeled DIN load to Large Marine Ecosystems and Relationship with Primary Production

Primary production is related to DIN load across the 64 LMEs

Rosalynn Lee and Seitzinger in prep.


**N Inputs to Continental Shelf From Land and Marine Sources**

- River inputs
- Atmospheric Deposition
- N\textsubscript{2}-fixation 100-200 Tg N/y
- Across Shelf Transport
- Burial

Rivers | Estuaries | Continental Shelf | Oceanic
Dynamic Biogeochemical/Hydrodynamic Model of the MAB
K. Fennel et al. 2006 GBC

- N Based Plankton Model
  Fasham et al. 1990

- Sediment Denitrification
  Seitzinger & Giblin 1996

River N Inputs

Across Shelf Transport
Coupled Hydrodynamic/NPZ Model
K. Fennel et al., 2006
Annual Primary Production

K. Fennel et al., 2006
Annual Primary Production

Denitrification
River Nutrients

K. Fennel et al. GBC 2006
K. Fennel et al. GBC 2006

$10^{10}$ mol N/y

River N: 1.8
Denitrification: 5.3
Denitrification of Land plus Marine Sources of N

- Terrestrial
  - Rivers
  - Estuaries
  - Continental Shelf
  - Oceanic

Denitrification, Tg N/y

- Terrestrial
- Groundwater
- Rivers & Lakes
- Estuaries
- Continental Shelf
- Oceanic OMZ

From: Seitzinger et al. 2006
Denitrification of N from Land-based & Marine Sources

River Export
67 Tg N/y

Modified from Seitzinger et al. 2006
Bring together denitrification scientists across a broad range of disciplines to advance:

- quantification of denitrification rates
- quantitative relationships between denitrification rates and controlling factors
- process-based models that can be used to scale-up site specific measurements to ecosystem, regional and global scales.

Steering Committee:
S. Seitzinger and E. Davidson (Co-Chairs), R. Lee (Post-doc)
M. Altabet, E. Boyer, M. Firestone, A. Giblin, W. Gilliam,
P. Groffman, L.P. Nielsen (Denmark), M. Scholes (S. Africa),
L. Schipper (NZ).
Atmospheric N Deposition to Coastal Ocean vs River Inputs

From Katye Altieri using data from Dentener et al. 2006
N Loads from rivers vs. Atmospheric Deposition on Shelf by Latitude

Tg N/yr

- 0-30N
- 0-30S
- 30-60N
- 30-60S
- 60-90N
- 60-90S

Rivers
Atm. Deposition
New nitrogen

Atmos. Deposition

Open Ocean

\( \text{N}_2 \)

\( \text{NO}_3^- \)

\( \text{NO}_3^- \)

Modified from Bronk
Atmospheric N Deposition to Ocean

1860  20 Tg N/y

**More than tripled

2000  67 Tg N/y

**Currently similar magnitude to N₂-fixation

N₂-fixation  ~100 Tg N/y

From Katye Altieri using data from Dentener et al. 2006

Krishnamurthy et al. 2007; Duce et al. in prep.
Acknowledgments

- Global NEWS workgroup
- UNESCO- IOC
- UNEP
- GEF
- NSF
- NOAA
- NASA
Global N, P and C river transport from watersheds to coastal systems
- Approach
- Magnitude and spatial patterns
- Drivers

Effect of land-based nutrient inputs

Fate of N input

Atmospheric N deposition to coastal and oceanic systems

Future directions
Questions

- How can we best link past and current N, P and C land-based inputs to coastal ecosystem effects at regional to global scales?

- How might nutrient inputs change under a range of future scenarios (development, climate, biofuels) and what are the consequences for marine ecosystems?