ATS 680A7, Experimental Course for Fall 2015

The Global Nitrogen Cycle

Instructor: Emily Fischer

Tuesday/Thursday, 11 – 11:50AM, ATS 101

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Office Hours: By Appointment.

Course Description: This course is focused on understanding the processes that regulate the cycling of nitrogen among and between the atmosphere, oceans and continents. Special emphasis will be placed on the role of the atmosphere in the global nitrogen cycle and how the global nitrogen cycle has changed due to human activities. The course will be structured as 1 lecture per week and 1 discussion period. Students will alternate leading weekly discussions on topic-relevant literature. The student will select 2-4 papers on the week's topic from the recent literature and prepare a 25 min overview oral presentation on the papers. They will then formulate questions for discussion and lead the class discussion of each topic. As a final project, each student will prepare a proposal for research on a topic of their choice related to the course materials. This proposal should be formatted and presented as a proposal to NSF for a postdoctoral research fellowship (http://www.nsf.gov/pubs/2014/nsf14509/nsf14509.pdf), including a relevant survey of literature, motivation, research objectives and proposed methods.

Course Learning Objectives:

1. Describe the forms and cycling of nitrogen in the atmosphere and other global reservoirs.
2. Critique current literature focused on the nitrogen cycle with a focus on the atmosphere.
3. Effectively summarize and facilitate discussions focused on recent literature related to the global nitrogen budget.
4. Develop a research proposal focused on nitrogen.

Prerequisites: ATS 621, or equivalent chemistry class experience, or permission of the instructor.

Grading: In-class Presentations: 50% / Discussion Participation: 20% / Proposal: 30%

The overall course grade will be made up of three different components: active in-class participation in the discussions (20%), a research proposal (30%), and a class presentation (50%) where each student leads the discussion of that week's assigned reading.

Grading criteria for discussion participation:

Grade	Criteria
F	• Does not participate.
D	• Present, not disruptive. • Tries to respond when called on but does not offer much. • Demonstrates very infrequent involvement in discussion.
C	• Demonstrates adequate preparation: knows the basics of the assigned journal articles, but does not show evidence of trying to interpret them. • Offers straightforward information (e.g., straight from the reading), without elaboration or very infrequently. • Does not offer to contribute to discussion, but contributes to a moderate degree when called on. • Demonstrates sporadic involvement in the discussions. • Alternatively, student participates but in a problematic way: talks too much, rambles, or interrupts others.
B	• Demonstrates good preparation: knows paper conclusions well, and has thought through their implications. • Offers interpretations and analysis of the papers (more than just repeating the author's analysis) to class. • Contributes well to discussion in an ongoing way: responds to other students' points, thinks through own points, questions others in a constructive way

	• Demonstrates consistent ongoing involvement.
A	• Student comes to class prepared and contributes readily to the conversation but does not dominate it. • Demonstrates excellent preparation: has analyzed assigned readings thoroughly, can relate papers to each other, and identify inconsistencies or questions. • Offers analysis, synthesis, and evaluation of assigned journal articles, e.g., combines pieces of the discussion to further the group's understanding of material. • Contributes in a very significant way to ongoing discussion: keeps analysis focused, responds very thoughtfully to other students' comments, enhances other's understanding by contributing to cooperative arguments/problem solving, suggests alternative ways of explaining difficult material • Demonstrates ongoing very active involvement.

Statement on Academic Integrity: This course will adhere to the CSU Academic Integrity Policy as found in the General Catalog (http://www.catalog.colostate.edu/FrontPDF/1.6POLICIES1112f.pdf) and the Student Conduct Code (http://www.conflictresolution.colostate.edu/conduct-code). At a minimum, violations will result in a grading penalty in this course and a report to the Office of Conflict Resolution and Student Conduct Services.

Contact Hours: 2 (At least 3 hours of effort are expected to complete reading and associated activities outside of class for each hour of class time.)

Week	Topic	Discussion Leader	Reading (subject to modification)
1	Overview Lectures: The Global Nitrogen Cycle	Emily Fischer	*Galloway* [2003]; *Galloway et al.* [2013]; *Galloway et al.* [2004]
2	Past Present and Future of Earth's Nitrogen Cycle	Student A	*Canfield et al.* [2010]; *Erisman et al.* [2013]; *Galloway et al.* [2003]
3	N_2O: Links with stratospheric O_3 and anthropogenic nitrogen fixation	Student B	*Bouwman et al.* [2013]; *Butterbach-Bahl et al.* [2013]; *Nevison and Holland* [1997]; *Randeniya et al.* [2002]; *Reay et al.* [2012]
4	NO and HONO emissions from soils	Student C	*Li et al.* [2014]; *Oswald et al.* [2013]; *Pilegaard* [2013]
5	Ammonia Emissions and Deposition	Student D	*Erisman et al.* [2008]; *Sutton et al.* [2013]
6	Organic Nitrogen in the Atmosphere	Student E	*Fischer et al.* [2014]; *Jickells et al.* [2013]; *Perring et al.* [2013]
7	Terrestrial N: N-fixation, Nr fate in agricultural systems	Student F	*Smil* [2002]; *Tilman et al.* [2002]
8	Terrestrial N: Ecosystem impacts and cycling	Student G	*Houlton et al.* [2007]; *Matson et al.* [2002]; *Vitousek et al.* [2013]
9	Proposal Writing	Emily Fischer	*Bourne* [2006]; *Kraicer* [1997]
10	Nitrogen in Aquatic Ecosystems	Student H	*Rabalais* [2002]
11	Nutrient inputs to water bodies	Student I	*Schindler et al.* [2008]; *Turner et al.* [2008]
12	Nitrogen in the Ocean	Student J	*Duce et al.* [2008]; *Krishnamurthy et al.*

			[2009]; *Naqvi et al.* [2008]
13	Nitrogen – Carbon Cycle Interactions	Student K	*Zaehle* [2013]
14	Evaluating Changes in the Nitrogen Cycle over time	Student L	*Geng et al.* [2014]; *Hastings et al.* [2009]; *Wolff* [2013]
15	Nitrogen in Climate Change	Student M	*Pinder et al.* [2012]; *Suddick et al.* [2013]
16	Final Exam Week		

Reading List

Bourne, P. E. (2006), Ten Simple Rules for Getting Grants, *PLoS Comput. Biol.*, *2*(2), e12,10.1371/journal.pcbi.0020012.

Bouwman, A. F., A. H. W. Beusen, J. Griffioen, J. W. Van Groenigen, M. M. Hefting, O. Oenema, P. J. T. M. Van Puijenbroek, S. Seitzinger, C. P. Slomp, and E. Stehfest (2013), Global trends and uncertainties in terrestrial denitrification and N2O emissions, *Philosophical Transactions of the Royal Society B: Biological Sciences*, *368*(1621).

Butterbach-Bahl, K., E. M. Baggs, M. Dannenmann, R. Kiese, and S. Zechmeister-Boltenstern (2013), Nitrous oxide emissions from soils: how well do we understand the processes and their controls?, *Philosophical Transactions of the Royal Society B: Biological Sciences*, *368*(1621).

Canfield, D. E., A. N. Glazer, and P. G. Falkowski (2010), The Evolution and Future of Earth's Nitrogen Cycle, *Science*, *330*(6001), 192-196.

Duce, R. A., J. LaRoche, K. Altieri, K. R. Arrigo, A. R. Baker, D. G. Capone, S. Cornell, F. Dentener, J. Galloway, R. S. Ganeshram, R. J. Geider, T. Jickells, M. M. Kuypers, R. Langlois, P. S. Liss, S. M. Liu, J. J. Middelburg, C. M. Moore, S. Nickovic, A. Oschlies, T. Pedersen, J. Prospero, R. Schlitzer, S. Seitzinger, L. L. Sorensen, M. Uematsu, O. Ulloa, M. Voss, B. Ward, and L. Zamora (2008), Impacts of Atmospheric Anthropogenic Nitrogen on the Open Ocean, *Science*, *320*(5878), 893-897.

Erisman, J. W., M. A. Sutton, J. Galloway, Z. Klimont, and W. Winiwarter (2008), How a century of ammonia synthesis changed the world, *Nature Geosci*, *1*(10), 636-639.

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Fischer, E. V., D. J. Jacob, R. M. Yantosca, M. P. Sulprizio, D. B. Millet, J. Mao, F. Paulot, H. B. Singh, A. Roiger, L. Ries, R. W. Talbot, K. Dzepina, and S. Pandey Deolal (2014), Atmospheric peroxyacetyl nitrate (PAN): a global budget and source attribution, *Atmos. Chem. Phys.*, *14*(5), 2679-2698,10.5194/acp-14-2679-2014.

Galloway, J. N. (2003), 8.12 - The Global Nitrogen Cycle, in *Treatise on Geochemistry*, edited by H. D. Holland and K. K. Turekian, pp. 557-583, Pergamon, Oxford.

Galloway, J. N., A. M. Leach, A. Bleeker, and J. W. Erisman (2013), A chronology of human understanding of the nitrogen cycle, *Philosophical Transactions of the Royal Society B: Biological Sciences*, *368*(1621).

Galloway, J. N., J. D. Aber, J. W. Erisman, S. P. Seitzinger, R. W. Howarth, E. B. Cowling, and B. J. Cosby (2003), The Nitrogen Cascade, *BioScience*, *53*(4), 341-356,10.1641/0006-3568(2003)053[0341:TNC]2.0.CO;2.

Galloway, J. N., F. J. Dentener, D. G. Capone, E. W. Boyer, R. W. Howarth, S. P. Seitzinger, G. P. Asner, C. C. Cleveland, P. A. Green, E. A. Holland, D. M. Karl, A. F. Michaels, J. H. Porter, A. R. Townsend, and C. J. Vöosmarty (2004), Nitrogen Cycles: Past, Present, and Future, *Biogeochemistry*, *70*(2), 153-226,10.1007/s10533-004-0370-0.

Geng, L., B. Alexander, J. Cole-Dai, E. J. Steig, J. Savarino, E. D. Sofen, and A. J. Schauer (2014), Nitrogen isotopes in ice core nitrate linked to anthropogenic atmospheric acidity change, *Proceedings of the National Academy of Sciences*, *111*(16), 5808-5812.

Hastings, M. G., J. C. Jarvis, and E. J. Steig (2009), Anthropogenic Impacts on Nitrogen Isotopes of Ice-Core Nitrate, *Science*, *324*(5932), 1288-1288.

Houlton, B. Z., D. M. Sigman, E. A. G. Schuur, and L. O. Hedin (2007), A climate-driven switch in plant nitrogen acquisition within tropical forest communities, *Proceedings of the National Academy of Sciences*, *104*(21), 8902-8906.

Jickells, T., A. R. Baker, J. N. Cape, S. E. Cornell, and E. Nemitz (2013), The cycling of organic nitrogen through the atmosphere, *Philosophical Transactions of the Royal Society B: Biological Sciences*, *368*(1621).

Kraicer, J. (1997), The art of grantmanship. Strasbourg: Human Frontier Science Program, *Available:* http://www.hfsp.org/how/ArtOfGrants.htm., *Accessed 31 July 2014*.

Krishnamurthy, A., J. K. Moore, N. Mahowald, C. Luo, S. C. Doney, K. Lindsay, and C. S. Zender (2009), Impacts of increasing anthropogenic soluble iron and nitrogen deposition on

ocean biogeochemistry, *Global Biogeochemical Cycles*, *23*(3), GB3016,10.1029/2008GB003440.

Li, X., F. Rohrer, A. Hofzumahaus, T. Brauers, R. Häseler, B. Bohn, S. Broch, H. Fuchs, S. Gomm, F. Holland, J. Jäger, J. Kaiser, F. N. Keutsch, I. Lohse, K. Lu, R. Tillmann, R. Wegener, G. M. Wolfe, T. F. Mentel, A. Kiendler-Scharr, and A. Wahner (2014), Missing Gas-Phase Source of HONO Inferred from Zeppelin Measurements in the Troposphere, *Science*, *344*(6181), 292-296.

Matson, P., K. A. Lohse, and J. H. Sharon (2002), The Globalization of Nitrogen Deposition: Consequences for Terrestrial Ecosystems, *Ambio*, *31*(2), 113-119,10.2307/4315223.

Naqvi, S. W. A., M. Voss, and J. P. Montoya (2008), Recent advances in the biogeochemistry of nitrogen in the ocean, *Biogeosciences*, *5*(4), 1033-1041,10.5194/bg-5-1033-2008.

Nevison, C., and E. Holland (1997), A reexamination of the impact of anthropogenically fixed nitrogen on atmospheric N2O and the stratospheric O3 layer, *Journal of Geophysical Research: Atmospheres*, *102*(D21), 25519-25536,10.1029/97JD02391.

Oswald, R., T. Behrendt, M. Ermel, D. Wu, H. Su, Y. Cheng, C. Breuninger, A. Moravek, E. Mougin, C. Delon, B. Loubet, A. Pommerening-Röser, M. Sörgel, U. Pöschl, T. Hoffmann, M. O. Andreae, F. X. Meixner, and I. Trebs (2013), HONO Emissions from Soil Bacteria as a Major Source of Atmospheric Reactive Nitrogen, *Science*, *341*(6151), 1233-1235.

Perring, A. E., S. E. Pusede, and R. C. Cohen (2013), An Observational Perspective on the Atmospheric Impacts of Alkyl and Multifunctional Nitrates on Ozone and Secondary Organic Aerosol, *Chemical Reviews*, *113*(8), 5848-5870,10.1021/cr300520x.

Pilegaard, K. (2013), Processes regulating nitric oxide emissions from soils, *Philosophical Transactions of the Royal Society B: Biological Sciences*, *368*(1621).

Pinder, R. W., E. A. Davidson, C. L. Goodale, T. L. Greaver, J. D. Herrick, and L. Liu (2012), Climate change impacts of US reactive nitrogen, *Proceedings of the National Academy of Sciences*, *109*(20), 7671-7675.

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Schindler, D. W., R. E. Hecky, D. L. Findlay, M. P. Stainton, B. R. Parker, M. J. Paterson, K. G. Beaty, M. Lyng, and S. E. M. Kasian (2008), Eutrophication of lakes cannot be controlled by reducing nitrogen input: Results of a 37-year whole-ecosystem experiment, *Proceedings of the National Academy of Sciences, 105*(32), 11254-11258.

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Tilman, D., K. G. Cassman, P. A. Matson, R. Naylor, and S. Polasky (2002), Agricultural sustainability and intensive production practices, *Nature, 418*(6898), 671-677.

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Wolff, E. W. (2013), Ice sheets and nitrogen, *Philosophical Transactions of the Royal Society B: Biological Sciences, 368*(1621).

Zaehle, S. (2013), Terrestrial nitrogen–carbon cycle interactions at the global scale, *Philosophical Transactions of the Royal Society B: Biological Sciences, 368*(1621).