Aspen Global Change Institute
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Biogeochemical Cycles, Air Quality, and Climate Change

Working Group 1B. Global Biogeochemical Cycles
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Background

Greenhouse gases (CO_2, CH_4, N_2O) concentrations are changing. CO_2 concentrations have increased x% (from to) in the last years. CH_4 has more than doubled (from ~800 ppbv to ~1800 ppbv) in the last 150 years. N_2O has increased from 275 ppbv to 315 ppbv during the same time period. The growth rate of all three gases accelerated rapidly during the last 50 years and contribute the majority of the warming during this period.

Understanding the relationship between concentrations and emissions is not straightforward, particularly for CH_4 and N_2O since those gases are chemically, as well as radiatively, active.

Currently, CO_2 emissions total about 7 Gt C/yr – about 6 Gt of which is from fossil fuels and cement production, and the reminder from tropical land-use change (estimate of Houghton is about 1.6 Gt but most researchers believe that this is probably overestimated. Uptake by oceans and northern forest uptake account for about 2.5 GtC/yr, atmospheric accumulation accounts for about 3.5 GtC/yr. Interannual climate variations, direct fertilization by atmospheric CO_2 as well as inadvertent N deposition likely produce imbalances in long- and/or short-term timescales.

Methane concentrations increased relatively steadily since the early 1980s but the growth rate slowed substantially in the 1990s. Causes for this slow-down are stabilizing or declining emissions and/or increasing sinks due to increasing OH. Recent research suggests that both forces are contributing to the declining growth rate. The short lifetime of CH$ (on order of 10 years) means that substantial and persistent reductions in emissions or increases in sinks can alter the climate change predictions made assuming steady increases in CH_4 in the future (as in previous IPCC scenarios).

The major source for N_2O is natural soils, primarily in the tropics. Other sources include biomass burning, nitrogenous fertilizer consumption and nylon production.

The major sources for CH_4 are natural wetlands, domestic ruminant animals, irrigated rice cultivation, biomass burning (natural and anthropogenic), and landfills, with minor contributions from sewage, oceans, hydrates, and termites. Biomass burning and natural wetlands are currently the most uncertain sources. In the case of biomass burning, uncertainties include: estimating burned areas, C density of vegetation biomass and soil C (including boreal peats), trace-gas emissions (CO_2, CH_4, N_2O, CO,???), and controlling processes (climate, …). The wetland methane sources is uncertain primarily due to the difficulty in determining how representative existing measurements are in the context of global wetlands. Processes at the site level are relatively well understood but extrapolating those processes to larger scales still needs validation. The remaining major sources, all anthropogenic, are pretty well understood with respect to processes, although the diffuse sources distributions (e.g., natural gas transmission, coal mining), together with the inherent variability and episodic nature of the emissions, pose some challenges.

Research Agenda

Field and Lab Experiments

microbial population changes in changing soil chemistry environments
microbial competition in soils
methane oxidation in oxic layer of wetland soils
methane oxidation in dry surface soils
N_2O emissions from tropical soils – need meas'ts of more ecosystems, agriculture, years

New Data Sets – most are spatially explicit

fundamental data sets needed in process-modeling studies and emission fields
some are one-time representations (1) others are temporal sequences (2);
the latter are or will eventually be modeled at least in part
historical land-use change - input to disturbance module of dynamic vegetation models
following list is a sampling – please add

Species	Frequency	Description
CH_4	1	microtopography distributions in wetland ecosystems
S-CH_4	1	sulfate-relevant lithology
CH_4	1	recalcitrance/lability of organic matter
CH_4	1	soil capacity to produce methane
S-CH_4	2	S-deposition (spatial and temporal)
N_2O, CH_4	2	fertilizer consumption by fertilizer type
CO_2	2	carbon density in vegetation biomass and soils
N_2O, CH_4	2	water management practices in rice

Model Development – usually offline development, simplified implementation in GCMs

Soil physics
H_2O movement/status (vert & horiz distribution of saturated soil (nonriverine wetlands)

Soil chemistry
interactions among lithology, soil texture, OM, H_2O, chem inputs, microb. activity

Linked surface water hydrology (rivers, lakes, riverine wetlands
CH_4 emission periods, nutrient transport in rivers and to oceans

Process model for biospheric CO_2 (dynamic vegetation models DVMs):
model exchange of C, H_2O, and energy
same models predict seas, interannual, decadal and centennial interactions between vegetation physiology/physiognomy and climate
development of models is well underway;
offline experiments have been done using climate to force models;
on the verge of full implementation of DVMs into GCMs
allows 2-way feedbacks between climate, biosphere, and BGC cycles

Disturbance module in DVM
represent realistic decay and regrowth of disturbed veg/soils
natural disturbance (eg wild fires) & anthro (eg land use change, pasture fires, lumbering)

Process model of CH_4 production-transport-oxidation-emission in wetlands
initial model developed and validated with available measurements
model development/improvement needed for tropical regions

Process model for CH_4 from rice
processes similar to those in wetlands BUT
very strong influence of management practices requires spatial and temporal input data on harvest areas, water regime, fertilizer use, cultivar characteristics