

The temporal analysis of surface albedo derived from Meteosat observations appears therefore appropriate for the monitoring of burnt areas. It reveals the importance of biomass burning impact on surface albedo at the continental scale. Since almost 20 years of Meteosat data is currently archived, these data represent an unprecedented source of information to study the inter-annual variability of such process.

B31B-0103 0830h POSTER

Land-cover Change Mediating Nitrogen Trace Gas Emissions From Savanna Soils of North Texas

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Soils of savanna ecosystems are known sources of nitrogen (N) oxide trace gases (nitric oxide: NO and nitrous oxide: N₂O). However, little is known about the spatial and temporal variation of N oxide emissions in southwest US rangelands, and no regional analyses have produced well-constrained estimates of the effect of large-scale woody encroachment of the N-fixing shrub, *Prosopis glandulosa*, on trace gas emission. The primary difficulty has been in determining range of N oxide emission values associated with changes in woody cover and variation in soil type.

Soil fluxes of NO and N₂O were measured during six observations over one year on nine sites spanning a range of plant canopy cover on two soil types. Local variability at a given site was examined through stratified measurements beneath tree canopy and in grass interspaces between canopies. Soil and air temperature as well as soil water content and canopy area were measured in conjunction with each sampling period. Relative measures of N availability were determined through laboratory assays of inorganic N content and nitrification potential.

Proportion of plant canopy cover was the dominant control on N oxide emissions. Soil NO fluxes increased linearly from 0.1 to 5.2 kg N-NO ha⁻¹ yr⁻¹ across a range of plant canopy area extending from 5 to 340 m². Soil NO fluxes were six times greater from sites located on clay loam soils than on shallow clay soils. However, soil NO fluxes were not statistically different from under the tree canopy and in the grassy inter-space within a given soil type. NO emissions were largest from all sites during the growing season (sampled May, July, August) when temperatures were warm and the canopy was in full foliage. Temperature was the dominant abiotic control on NO emissions from all sites soil moisture content was a poor predictor of NO emissions, however, volumetric soil water contents below 20% appeared to restrict the response of NO to temperature.

Linking these relationships with regional scale data from MODIS and AVIRIS will contribute greatly to our understanding of biogenic nitrogen production, transport and redeposition issues in the Southwestern U.S.

B31B-0104 0830h POSTER

A Regional Modeling Study of the Influence of Urban Land Cover Change on the Lower Atmosphere in Baltimore-Washington DC

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The land-use and land cover (LULC) history of the Baltimore-Washington region has been intensively

studied through a variety of environmental research collaborations and regional partnerships. One such partnership, the Baltimore-Washington Regional Collaboratory, involved multiple Federal and local agencies co-operating on a 200-year urban growth study in the Chesapeake region. Information from this study on pre-1900 and current LULC conditions for the Baltimore-Washington DC area was integrated with data from other sources to construct different lower boundary conditions for a series of simulations using the Colorado State University (CSU) Regional Atmospheric Modeling System (RAMS). We use the RAMS simulations to diagnose the extent and nature of the effect of urban anomalies in surface heat, moisture, and momentum on mid-summer local and regional climate.

The experimental design adopted for this study takes advantage of the grid-nesting capability of RAMS. A fine grid with 1km horizontal resolution was nested into a coarser 5 km grid, which extends from southern Pennsylvania, Maryland, to parts of Virginia, and West Virginia. Two sets of month-long simulations for July 2000 were conducted with RAMS running in parallel on a 26-processor cluster of computers at the Cooperative Institute for Research in the Atmosphere (CIRA), CSU. In the first set of simulations, we initially used satellite-derived current land cover data as the lower boundary condition in a 31-day RAMS run. We then replaced this data with the pre-1900 land cover data for the same region and ran a similar RAMS simulation. Identical observed meteorology was retained for the lateral boundary conditions in both cases. The model results for the initial run were validated with July 2000 surface climate data and flux measurements of sensible and latent heat from sites located within the fine grid model domain.

Additional simulations were conducted to compare RAMS model performance using prescribed land surface conditions with results from a physically based scheme for urban energy budget coupled to RAMS. The urban surface scheme used here is the Town Energy Budget (TEB) model recently developed at the Center for Meteorological Research (CNRM), France. The TEB model allows for a refinement of model computed radiative budgets, heat and momentum based on a generalization of the classic canyon approach. Results from both sets of simulations, and the implications, for surface climate, of the driving human-induced land cover transformations are discussed.

B31B-0105 0830h POSTER

Quantitative Reconstruction of Grassland and Forest Cover in Southern Sweden Inferred from Fossil Pollen Records

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When reconstructing past land-cover changes induced by humans at local to regional scales, primary interest is to quantify vegetation cover of forest and grassland. Fossil pollen records have great potential in that respect. However, quantitative reconstruction using pollen always require well-established pollen/vegetation relationship in the region of interest. In particular, pollen productivity and dispersal are two major factors, controlling the pollen representation of the surrounding vegetation in a basin (lake or bog), thus need a better understanding. Based on empirical studies in the ancient cultural landscape of southern Sweden, we have obtained pollen productivity estimates (PPE) for major taxa relevant for that region. These PPE show that arboreal taxa produce 10-40 times as much pollen as non-arboreal taxa. Considering significant input of background pollen dominated by arboreal taxa the area of open grassland in the past could often be underestimated when estimated directly from non-arboreal pollen percentages in fossil pollen records. To better understand the problem, we compare quantitative estimates of vegetation cover inferred from fossil pollen records in two regions of southern Sweden, where vegetation composition and structure are significantly different. One region is dominated by cultivated and grazed open-land with scattered wood patches (OPEN), while the other region is mostly forested with scattered patches of cultivated and grazed land (SEMI-OPEN). The reconstruction follows the "Landscape Reconstruction Algorithm" (LRA) approach, which estimates vegetation cover within a given catchment area around the pollen site using PPE and estimates of background pollen for that region. The results are compared to the historical records in the region at several time horizons to validate the LRA approach. Our results show that open grassland cover is always underrepresented when only NAP percentages

are used, with various degrees depending on regional vegetation composition and structure.

B31C MC: 122 Wednesday 0830h

Nonlinearity and Complexity in the Biogeosciences I (joint with NG)

Presiding: J F Reynolds, Duke University; P Canadell, GCTE International Project Office

B31C-01 0835h INVITED

Nonlinear Changes in Soil Properties and Their Impact on Ecosystems

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Soils are open systems that act as a membrane at Earth's surface. Water and dissolved acids are the main materials transferred into soils, whereas water and lithogenic solutes dominate the output with the net result being depletion of rock forming constituents such as silica and base cations that are also ecosystem nutrients. The time-dependent coupling of water flux and chemical reactions determines the nature of the colloidal phase that is responsible for nutrient retention. Pedogenesis is a biogeochemical process that is constrained by thermodynamics, but still maintains considerable flexibility as a result of parallel reaction kinetics and a spatially heterogeneous matrix. In the open system, there are many processes that are governed by nonlinear response to changes in environmental variables and/or internal soil properties. From a thermodynamic perspective, the chemistry of pedogenesis is characterized by a number of thresholds. Simultaneous acid-base, ion exchange, redox and mineral transformation reactions interact to determine the direction and rate of change. Over time, the reaction of atmospheric acids with soil bases changes the acid neutralizing capacity of soil to an extent that is controlled by the prevailing buffering reactions. The amount of buffering reaction and effect on pH depend on the nature of the reactive species, their relative amounts, and their respective rates of reaction. Ion exchange and surface complexation reactions consume protons in the short term but long-term buffering derives from mineral weathering. The nature of the governing reactions is such that soils are well buffered to pH change in the alkaline and acid regions but far less so in the neutral to slightly acid zones. In an analogous fashion, organic matter may drive oxidation-reduction processes through a stepwise consumption of electron acceptors (thereby producing thresholds). Mineralogical change tends to occur in a serial, irreversible fashion that, under favorable environmental conditions, can lead to large accumulations of specific minerals whose crystallinity changes over time. These accumulations and associated ripening processes can channel soil processes along existing pathways or they can force thresholds by causing changes in water flux and kinetic pathways. Examples of the influence nonlinear pedogenic change on ecosystem properties can be well illustrated using chronosequences and climosequences sampled on the Hawaiian Islands.

B31C-02 0855h

Extremes and Threshold Controls on Rangeland Ecosystems and the Evolution of the Non-Equilibrium Paradigm

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The dynamics of rangeland ecosystems involve many factors whose simultaneous action and complex interactions are poorly understood at the relevant temporal and spatial scales. Nonlinear, complex interactions among the drivers of change are some of the main sources of this uncertainty. This includes regime shifts in climate, water movement across landscapes (e.g., key feedbacks between rainfall interception, soil erosion, and nutrient transport), exotic species invasions, and plant physiological responses to episodic rainfall events. In recognition of these nonlinearities, during the past several decades there has been a

paradigm switch in ecology, from a balance of nature to equilibrium/stability to non-equilibrium. Arguably, in no other area of ecology has the equilibrium/non-equilibrium debate been as influential in shaping science discourse, research priorities, and management approaches as in arid and semiarid rangeland grazing systems. For over 50 years, the equilibrium or linear perspective has been the dominant model used for assessment and management in rangeland ecosystems, but it is now recognized that the equilibrium model per se does not, for example, account for the existence of multiple climax states that may arise out of unique plant-soil-atmosphere interactions, and that removing a disturbance (e.g., grazing) does not automatically result in a resumption of a orderly succession progression. To introduce this session, I will present examples of non-linear extremes and threshold controls on coupled water and nitrogen dynamics in arid/semiarid ecosystems and show how this work has contributed to the evolution of the non-equilibrium paradigm in rangeland ecology.

B31C-03 0910h

Fast Vegetational Responses to Late-Glacial Climate Change

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How rapidly can natural ecosystems respond to rapid climate change? This question can be addressed by studying paired paleoecological and paleoclimatological records spanning the last deglaciation. Between 16 and 10 ka, abrupt climatic oscillations (e.g. Younger Dryas, Gerzensee/Killarney Oscillations) interrupted the general warming trend. Rates of climate change during these events were as fast or faster than projected rates of change for this century. We compiled a dozen high-resolution lacustrine records in North America and Europe with a pollen record and independent climatic proxy, a clear Younger Dryas signal, and good age control. Cross-correlation analysis suggests that vegetation responded rapidly to late-glacial climate change, with significant changes in vegetation composition occurring within the lifespan of individual trees. At all sites, vegetation lagged climate by less than 200 years, and at two-thirds of the sites, the initial vegetational response occurred within 100 years. The finding of rapid vegetational responses is consistent across sites and continents, and is similar to the 100-200 year response times predicted by gap-scale forest models. Likely mechanisms include 1) increased susceptibility of mature trees to disturbances such as fire, wind, and disease, thereby opening up gaps for colonization, 2) the proximity of these sites to late-glacial treeline, where climate may directly control plant population densities and range limits, 3) the presence of herbaceous taxa with short generation times in these plant communities, and 4) rapid migration due to rare long-distance seed dispersals. Our results are consistent with reports that plant ranges are already shifting in response to recent climate change, and suggest that these shifts will persist for the next several centuries. Widespread changes in plant distributions may affect surface-atmosphere interactions and will challenge attempts to manage ecosystems and conserve biodiversity.

B31C-04 0925h INVITED

Biocomplexity, Complicatedness, and Simplicity in the Lower Mississippi Region

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The Lower Mississippi is a large and diverse region comprising a landscape, climate, hydrologic, ecological and economic systems. We illustrate its complexity by examining scaling behavior for the digital line graph (DLG) drainage system, streamflow from 1931 to 1998, and land cover based on 1-kilometer USGS gridded data. But any attempt to characterize the biocomplexity of the region as a whole requires an appreciation of complicatedness as well. A group of Tulane University and USGS scientists have been exploring this problem by using large databases to determine the possibility of low-dimensional data structures that may characterize

the system. The approach is rooted in a complicated view of linkages (both direct and feedback) among the major components cited in the first sentence. This exercise has not only given us a more integrated view of the system but has helped us appreciate the difficulty of maintaining productive discourse among many disciplines. Nevertheless, looming over all of these considerations of complexity is the simple vision of the river system as a plumbing diagram in which the major waterways must be managed in order to maintain river transportation, drinking water, and freedom from floods.

URL: <http://members.home.net/ldecola/graphics/streamflow.gif>

B31C-05 0945h INVITED

Complex Behavior of Contaminant Flux and the Ecology of the Lower Mississippi River

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This presentation is an overview of a collaborative NSF/USGS/Tulane funded multi-scale study of the Lower Mississippi River system. The study examines the system in three major dimensional realms: space, time, and complexity (systems and their hierarchies). Researchers at Tulane University and the U.S. Geological Survey have initiated a collaborative effort to undertake the study of interacting elements which directly or indirectly affect the water quality, ecology and physical condition of the Mississippi River. These researchers include experts in the fields of water quality chemistry, geochemistry, hydrologic modeling, bio-engineering, biology, fish ecology, statistics, complexity analysis, epidemiology, and computer science. Underlying this research are large databases that permit quantitative analysis of the system over the past 40 years. Results to date show that the variation in discharge and the contaminant flux scale independently both exhibit fractal scaling, the signature geometry of nonlinear dynamical and complex systems.

Public perception is that the Lower Mississippi River is a health hazard, but for the past decade, traditional water quality measurements show that contaminants are within current regulatory guidelines for human consumption. This difference between public perception and scientific reality represents a complex scientific and social issue. The connections and feedback within the ecological system and the Mississippi River are few because engineering structures isolate the lower Mississippi River from its surroundings. Investigation of the connections and feedback between human health and the ecological health of the River and the surrounding region as well as perceptions of these states of health - holds promise for explaining epidemiological patterns of human disease.

B31C-06 1025h INVITED

Regime Shifts in Ecosystems and Lakes in the Sahel: A Review

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A growing body of literature now points to the very strong coupling between climate, land surface processes, hydrology, and ecosystem dynamics in the Sahel region of Africa. In this presentation, we will review recent modeling results that illustrate two important processes.

First, we will review how the coupling of vegetation and climate over the Sahel can possibly lead to

regime shifts between alternative wet and dry conditions and sometimes maintaining these conditions for many decades and centuries. Several independent modeling studies have concluded that the vegetation dynamics (growth, competition, and succession) are crucial in the ability of the Sahel to bifurcate into two alternative states.

Second, we will review how hydrological processes in the Sahel can be affected by both climate changes and human activities. In particular, we will show how Lake Chad may be responding to two major forces: an initial change in climate, followed-by an increased demand for irrigation water in the basin. We will review modeling and observational evidence for a proposed feedback, whereby human activities may have amplified the response of Lake Chad to drought.

In summary, we will discuss a possible chain of events that links climate, ecosystems, and lakes, through a series of feedback loops. In this conceptual model, the Sahel illustrates the importance of nonlinear processes and coupling between different environmental systems.

B31C-07 1045h INVITED

Nonlinear hydrological dynamics on a desert bajada

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Water movement forms an integral part of the dynamics of desert ecosystems, with important feedbacks with soil erosion and nutrient transport. Modelling the hydrological dynamics of such ecosystems is thus integral to their understanding. Field data have been collected at the Jornada Basin Long-Term Ecological Research site over the last seven years using rainfall-simulation experiments. These data have demonstrated important nonlinear relationships in the processes of rainfall interception, stemflow, infiltration, runoff dynamics, erosion and nutrient transport. In order to understand the impacts of these relationships at the bajada scale, monitoring of natural events in small catchments and over larger areas using stock ponds, have been carried out. The results from these sites are compared with model runs parameterized using the small-plot data. The dynamics at the bajada scale are shown to be primarily a function of the spatial and temporal pattern of rainfall events. Spatial connectivity of different vegetation zones and the pattern of bare ground and plants within them is shown to have a secondary effect.

B31C-08 1105h

Nonlinear responses of desert shrubs to episodic rainfall events

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The physiological responses of desert shrubs to rapidly varying soil and atmospheric water status are equivocal. While much of the wide variations in observed responses in gas exchange and plant water potential can be readily attributed to nonlinear plant-soil-atmosphere couplings, there is a paucity of data to quantify these behaviors in the field. This motivated us to conduct an integrated field and modeling study on *Larrea tridentata*, the dominant shrub of North American warm deserts. We monitored photosynthesis, stomatal behavior, and water potential of 16 individual shrubs exposed to natural and simulated rainfall during two growing seasons at a field site in southern New Mexico. We use these field data to develop a new photosynthesis (A) model that explicitly links internal CO₂ (Ci) and stomatal conductance (g). A threshold response is assumed for instantaneous g such that stomata operate at their maximum g (g_{max}) for low vapor pressure deficits (VPD); thereafter, g decreases nonlinearly with increasing VPD. Predawn water potential and growing temperature interact with VPD to affect g and g_{max}. Ci is a linear function of g and the intercept is the minimum achievable Ci, which varies with temperature and light intensity. This model is able to reproduce *Larrea's* responses to episodic soil and atmospheric water availability, capturing the large diurnal and seasonal fluctuations in A, g, and Ci. We use this model to show

that the many conflicting conclusions regarding desert shrub responses to rainfall are explained by the lack of sufficient field data and by several key nonlinear plant-soil-atmosphere couplings.

B31C-09 1120h

Potential Changes to Fire Patterns in Amazonia

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Fires are major disturbances for ecosystems in Amazonia. They affect vegetation succession, change nutrients and carbon cycling, and modify atmosphere composition. Fires in Amazonia are strongly related to land-use, land-cover and climate conditions. Because these factors are expected to change in the future, models are needed to evaluate the consequences of potentially different conditions. Here we present a new fire model developed by relating satellite fire information to corresponding statistics on climate, land-use and land-cover. The model is able to reproduce the main features of the fire behavior in Amazonia. To evaluate potential changes in fire patterns in the future, we applied the model under different scenarios of climate conditions and future development of the region. The results show that in response to these scenarios, there may be substantial changes in the frequency and patterns of fires in the future. The implications of these results will be discussed in terms of the carbon cycle, forest coverage, and atmospheric fluxes.

B31C-10 1135h

Nitrogen deposition and sensitive ecosystems: a case study from the San Francisco Bay Area

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Nitrogen deposition from urban smog can greatly affect local ecosystems. This paper examines a complex situation in the Santa Clara Valley, CA where N-deposition from existing, new, and proposed developments threatens an ecosystem supporting numerous rare, threatened, and endangered species. Grasslands on nutrient-poor serpentine soils are being invaded by nutrient-demanding introduced annual grasses, driven by dry N-deposition of about 10 kg ha⁻¹ yr⁻¹. These grass invasions threaten the native biodiversity of the serpentine grasslands, including the federally-protected Bay checkerspot butterfly. Additional NO_x and NH₃ sources planned for the region include a 600 MW natural gas fired power plant, industrial parks that may eventually draw 20,000 to 50,000 additional cars per day, 25,000 housing units, and associated highway improvements. Ongoing mitigation proposals include purchase and long-term management of hundreds of hectares of habitat.

The situation is a model for understanding N-deposition from a scientific and policy viewpoint. Fundamental biogeochemical questions include: 1) What are the relative contributions of NO_x and NH₃ to increased N-deposition? NH₃ slip from power plant NO_x scrubbers can release more reactive nitrogen than is removed as NO_x, and modern automobiles release NH₃ in addition to NO_x. 2) How are N-emissions transported, chemically modified, and deposited on the local ecosystems, and are these processes adequately captured in regulatory models? How do point sources differ from line sources such as a heavily traveled freeway? 3) What are the effects of chronic N-deposition on the ecosystem, and is there a critical load or a steady cumulative effect? 4) What are the effects of management such as fire, grazing, mowing on N-cycling and plant composition? Policy issues include: 1) What are the incremental impacts of individual projects relative to high background deposition, 2) What margin of safety should be built into modeling and impact assessment? and 3) What are the most effective mitigation options?

B32A MC: Hall D Wednesday 1330h

Soil Biogeochemistry

Presiding: J Kimble,
USDA-NRCS-NSSC

B32A-0106 1330h POSTER

The Use of EMI and Electrical Instruments for Estimating Soil Properties to Help in Mapping

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Electromagnetic induction (EMI) is a very rapid and relatively inexpensive means for delineating soils and soil properties at a variety of scales. Ground-level measurements of four different EMI devices (EM38, EM31, Dualem-2 and Dualem-4 meters) and an electrical resistivity implement (Veris 3100) were compared and used to assess the depth to sand and gravel within an area mapped as predominantly as Warsaw but with inclusions and also small areas of other soils (fine-loamy over sandy or sandy skeletal, mixed superactive, mesic Typic Argiudolls). All five tools produced similar spatial patterns of apparent conductivity. Within the study site, measured depths to sand and gravel averaged 0.96 m and ranged from 0.33 to 1.85 m. Depths to sand and gravel were most strongly correlated with measurements obtained with the EM31meter in the vertical dipole ($r = 0.811, 0.002$ level) orientations, and the Dualem-4 meter in the horizontal coplanar ($r = 0.765, 0.005$ level) geometry. Lack of stronger correlations was attributed to variations in soil properties and the depth and volume of soil materials sounded with each instrument. Variations in the degree of correlation between apparent conductivity and depth to sand and gravel demonstrate the importance of selecting an instrument and dipole orientation that provide the maximum response within the depth of interest.

B32A-0107 1330h POSTER

Soil organic radiocarbon and mineralogy at two coastal California sites

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As the atmospheric carbon dioxide concentration rises it becomes increasingly important to understand the mechanisms that control carbon sequestration in carbon pools such as soils and ocean sediments. Mineralogy and soil grain size have both been hypothesized to regulate soil carbon storage. On volcanic soils, carbon storage correlates best with a mineralogical property, amorphous mineral content. However, volcanic soils are relatively uncommon and weather to unusually high concentrations of amorphous minerals.

Two chronosequences of soil terraces occurring along the coast of California provide the opportunity to study the relationship between a range of mineral

types, soil carbon content, soil radiocarbon age, and grain size on more common Alfisol soils. One site is located close to the mouth of the Mattole River, near Eureka, CA, and the second site is located close to Santa Cruz, CA. Both series of chronosequences formed on similar parent material, although the Mattole site receives approximately twice the rainfall of the Santa Cruz site. Through analysis of relationships between soil mineralogical properties, organic matter content, and soil radiocarbon age, we examine potential controls on soil carbon turnover.

B32A-0108 1330h POSTER

Fingerprinting of Soil Organic Matter in the Arctic to Help Predict Carbon Dioxide Flux

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It is estimated that a doubling of atmospheric carbon would result in a temperature increase at the high latitudes of 4 degrees C in summer and 17 degrees C in winter. The resultant warming and drying of Northern soils could result in an increase in the decomposition rate of soil organic matter (SOM) and increase in carbon dioxide flux to the atmosphere. Based on a recent study on SOM in the Kuparuk River basin, the age of SOM in the upper permafrost layers ranges from 6000-8000 yrs B.P., with some older than 12,000 yrs. B.P. Some readily degradable SOM is preserved because of frozen conditions while other matter is preserved due to its inherent biological recalcitrance. As such, not all SOM would be equally susceptible to biodegradation in a warmer climate.

Fingerprinting of organic matter by pyrolysis-GC/MS was used to compare the relative distribution of specific classes of organic compounds in soil samples. The relative susceptibility of the SOM in each soil sample to microbial degradation was compared based on correlations between pyrolysis fingerprints and carbon dioxide evolution. Pyrolysis-GC/MS fingerprinting was then performed on more than 100 soils sampled from the Kuparuk River basin, the western Alaska transect, Canada, Norway and Siberia.

Charts were prepared showing the characteristics of SOM in soils with the greatest and least propensity to contribute carbon dioxide to the atmosphere under conditions of substrate-limited biological decomposition. The calibration and use of pyrolysis-GC/MS make it practical to analyze hundreds of samples in the time it presently takes to analyze a single sample by laboratory or field incubation techniques.

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Do anaerobic microsites control soil methane flux?

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Understanding the exchange of methane between soils and the atmosphere remains one of the highest priorities for climate change research. To explain the biophysical basis of soil methane flux, we have tested the hypothesis that soil methane emissions are controlled by the distribution of anaerobic micro-sites in soils. Examination of this hypothesis depends on separating productive and consumptive processes within natural soils. We applied a new ¹³CH₄-isotope pool dilution technique to natural gradients in soil moisture in both tropical and temperate ecosystems. We observed a highly nonlinear response of methane flux to increasing soil moisture driven primarily by a stepwise increase in variance of methane production in wetter soils. Neither methane consumption nor carbon supply could explain the observed variations in methane emissions across the moisture gradients. Instead, we found soils to have a highly variable mixture of methanogenic and non-methanogenic pools of energy flow, and that the development of soil micro-sites appears critical for controlling this mixture. We conclude that only a small fraction of mineralization must proceed through methanogenic pathways before soils have positive net methane flux.