→ 2nd TERRABITES SYMPOSIUM

6 - 8 February 2012 | ESA-ESRIN | Frascati (Rome), Italy

ABSTRACT BOOK

changes in the Earth's climate. To quantify the role of anthropogenically induced soil development and erosion in the Earth system, we developed a new module of global soil dynamics: soil formation, erosion, and sediment transport, that is suitable for global application at 0.5° resolution. We incorporated this soil module into the LPJ-DGVM and performed a series of simulations to quantify the spatial and temporal pattern of global soil change over the Holocene.

The soil formation module models bedrock-to-soil conversion rates as exponentially decreasing with soil depth. Parameters for soil formation in different geological units were extracted from a review of existing literature. Our global soil erosion formulation is based on the Revised Universal Soil Loss Equation (RUSLE), but importantly accounts for sediment deposition and the net export of sediment out of a relatively large and geomorphologically heterogeneous gridcell. Our new module was developed by running the detailed soil erosion-deposition model WaTEM/SEDEM at 3 arc-second resolution to derive generalized topographical scaling relations that accurately represent hillslope length, slope gradient and sediment delivery ratio. We show that, at large spatial scale, sediment delivery ratio and the area affected by sediment deposition can be easily estimated from topographical parameters such as mean LS factor and wetness index. We include the feedback between soil formation and soil erosion by adjusting the soil erosion rates for soil depth and stoniness.

The results of our Holocene-long simulations indicate that millennia of human impact, mainly deforestation and cultivation, led to exhaustion of soil resources in many parts of the world. In particular, the eastern and southern Mediterranean, the northern Andes, and southern China were strongly affected by anthropogenic soil erosion. Some areas experienced declining rates of soil loss already in the early first millennium CE because of total removal of the soil column. Cumulative carbon emissions to the atmosphere over the Holocene as a result of anthropogenic soil erosion could have approached 200 Pg. Remote sensing-based global maps of topography, soils, and bedrock geology that have recently become available are a valuable resource that will improve our ability to model soil dynamics for the past and future.

Session 4: Quantifying Community Scale Processes for Vegetation Models

Tree-Grass Dynamics in Savannas: connecting ecological Knowledge and Dynamic Global Vegetation Models

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Terrestrial vegetation is an interactive component of the climate system. Dynamic Global Vegetation Models (DGVMs) simulate vegetation dynamics at the global scale and include it into Earth System Models. DGVMs are mostly based on the carbon balance of above- and below-ground biomass, and vegetation dynamics are influenced by climatic conditions and a variety of disturbances. They include a limited number of mechanisms to represent different types of vegetation and disturbances. This is because the models treat globally all vegetation in the same way, and regional differences are included only varying the importance of the various mechanisms across the world.
DGVMs realistically reproduce the distribution of the majority of the world biomes, although some of them have problems in predicting e.g. tree-grass savanna. Savannas are characterized by the coexistence of trees and grasses and cover about a fifth of the land surface. Savannas have been long studied in ecology, with several studies exploring the nature of tree-grass competition and coexistence. Recent studies show that in the driest savannas, potential tree cover displays a maximum value. This maximum tree cover increases with mean annual rainfall, depending on water availability, until it saturates at a certain rainfall. Therefore, some internal mechanism is limiting maximum tree cover below that level, leading to tree and grass coexistence. For rainfall above that level, both forests and savannas are observed, and fires become an essential disturbance for savanna persistence.
Savannas are expected to undergo major changes due to increasing temperature and CO2 concentration,

modified rainfall patterns and variations in fire regimes. Such changes could have larger effects on global biochemical cycles than for any other biome, due to their extent and large productivity.
Here we analyze how tree-grass relationships are described in different DGVMs, considering which elements are missing with respect to the main current ecological theories. We perform a comparative analysis of the ecological mechanisms represented in the different DGVMs. We aim to identify how the ecological knowledge could be implemented into the DGVMs, to improve understanding and predicting tree-grass dynamics across the globe, for present climate conditions and future scenarios of climate changes.

Poisson-Voronoi Diagrams and the Polygonal Tundra

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Sub-grid and small scale processes occur in various ecosystems and landscapes (e.g., periglacial ecosystems, peatlands and vegetation patterns). These local heterogeneities are often important or even fundamental to better understand general and large scale properties of the system, but they are either ignored or poorly parameterized in regional and global models.
Because of their small scale, the underlying generating processes can be well explained and resolved only by local mechanistic models, which, on the other hand, fail to consider the regional or global influences of those features. A challenging problem is then how to deal with these interactions across different spatial scales, and how to improve our understanding of the role played by local soil heterogeneities in the climate system. This is of particular interest in the northern peatlands, because of the huge amount of carbon stored in these regions. Land-atmosphere greenhouse gas fluxes vary dramatically within these environments. Therefore, to correctly estimate the fluxes a description of the small scale soil variability is needed.

Applications of statistical physics methods could be useful tools to upscale local features of the landscape, relating them to large-scale properties. To test this approach we considered a case study: the polygonal tundra.
Cryogenic polygons, consisting mainly of elevated dry rims and wet low centers, pattern the terrain of many subartic regions and are generated by complex crack-and-growth processes. Methane, carbon dioxide and water vapor fluxes vary largely within the environment, as an effect of the small scale processes that characterize the landscape. It is then essential to consider the local heterogeneous behavior of the system components, such as the water table level inside the polygon wet centers, or the depth at which frozen soil thaws.

We developed a stochastic model for this environment using Poisson-Voronoi diagrams, which are able to upscale statistical large scale properties of the system taking into account the main processes within the single polygons. We then compare the results with available recent field studies and demonstrate that the model captures the main statistical characteristics of the landscape and describes its dynamical behavior under climatic forcings (e.g., precipitation and evapotranspiration). In particular, we model and analyze water table dynamics, which directly influences greenhouse gas emissions and changes in the system. Hydraulic interconnectivities and slow large-scale drainage may also be investigated through percolation properties and thresholds in the Voronoi-Deleaunay graph.

Modelling Plant Adaptation: incorporating climate-driven Trait Variability into a DGVM

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DGVMs represent vegetation by a few discrete classes with constant trait values, so called Plant functional types (PFTs), but this hampers the accurate modelling of future climate due to the limited ability to account for plant-atmosphere feedbacks. A plant traits-based approach in modelling vegetation dynamics may help