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Dynamics of the global carbon cycle: a number of simple low-parametric closed models

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A set of simple closed global carbon cycle models consisting of three to eight reservoirs is developed and calibrated by modern and pre-industrial “storage-flow” schemes. Any flow connecting two reservoirs depends only on storages in them either linearly, or in a bi-linear (Lotka-Volterra) way, or as a function with saturation.

To study the functioning of the global carbon cycle an existence, stability and bifurcations of equilibria and periodic solutions are considered using the total amount of carbon and the rates of anthropogenic input and land-use to the atmosphere as bifurcation parameters. The pre-industrial carbon balance is shown to be stable. It means that if anthropogenic carbon emission is stopped the Earth biogeochemical system (atmosphere, land biota, ocean and lithosphere) will come back to the initial balance.

The number and stability of stationary states in this set of models are shown to be kept but the dynamics of carbon reservoirs essentially depends on calibration of flows responsible for the matter exchange between atmosphere and terrestrial biota. The designed set of models is established to adequately reflect degrees of inertia for carbon reservoirs by a biogeochemical point of view.

Relaxation times to the stable pre-industrial equilibrium for carbon storage values in the basic model are investigated under perturbation of this equilibrium without an anthropogenic input. However, the pre-industrial equilibrium is not stable relatively to permanently acting anthropogenic perturbation. Another steady state in the model, more hypothetical than real, can be characterized by disappearing the terrestrial biota compartment.

Numeric simulation of the system trajectories under the modern value of anthropogenic flux shows that the system becomes unstable and a carbon contents in the

atmosphere grows up to approximately 1100 GtC and then slightly going to the stable state. If emission continues up to the end of fossil fuel reserves, the system does not converge to a new steady state. Emission of carbon to the atmosphere is compensated by its stock to terrestrial biota and oceans.

In five-compartment model where carbon of biota and soils is separated, anthropogenic emission growth can lead to the “catastrophic” equilibrium without terrestrial carbon that is removed through the atmosphere into oceans during several hundreds of years. The sequence of models with six, seven and eight reservoirs allows one to study roles of surface and deep and upper ocean biota in dynamics of the global carbon cycle.

Embedding of equation for the simplest climatic factor – the globally averaged annual temperature of the surface - and linking it with main intercompartment flows modify the model and allow one to obtain climate-induced boundaries of stability domains for possible equilibrium of global carbon cycle.

Temperature variation in accordance with different climatic scenarios, as well as human perturbations trend, initiates the transition scheme between different equilibriums thus simulating probable tendencies in functioning of coupled climatic and biotic machines on the Earth.

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