



Earth system modeling with complex dynamic human societies: the copan:CORE World-Earth modeling framework

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Analysis of Earth system dynamics in the Anthropocene requires to explicitly take into account the increasing magnitude of processes operating in human societies, their cultures, economies and technosphere and their growing entanglement with those in the physical, chemical and biological systems of the planet. This work (i) introduces design principles for constructing World-Earth models (WEM), i.e. models of social-ecological co-evolution on up to planetary scales, and (ii) presents the copan:CORE open source software library that provides a simulation modeling framework for developing, composing and running such WEMs based on the proposed principles. copan:CORE is an object-oriented software package currently implemented in Python. It provides components of meaningful yet minimal collections of closely related processes in the Earth System that can be plugged together in order to compose and run WEMs. Developers can supplement the already existing model components with additional components that are based on elementary entity types, e.g., grid cells, or fundamental process taxa, e.g., environment or culture. To illustrate the capabilities of the framework, this paper presents a WEM example implemented in copan:CORE that combines a variety of model components and interactions thereof. Due to its modular structure, the simulation modeling framework enhances the development and application of integrated models in Earth system science but also climatology, economics, ecology, or sociology, and allows combining them for interdisciplinary studies such as risk assessment including explicitly the dynamics of human behavior and decision making.