Implementation of methane cycling for deep time, global warming simulations with the DCESS Earth System Model (Version 1.2) - DTU Orbit (12/12/2018)

Geological records reveal a number of ancient, large and rapid negative excursions of carbon-13 isotope. Such excursions can only be explained by massive injections of depleted carbon to the Earth System over a short duration. These injections may have forced strong global warming events, sometimes accompanied by mass extinctions, for example the Triassic-Jurassic and End-Permian extinctions, 201 and 252 million years ago. In many cases evidence points to methane as the dominant form of injected carbon, whether as thermogenic methane, formed by magma intrusions through overlying carbon-rich sediment, or from warming-induced dissociation of methane hydrate, a solid compound of methane and water found in ocean sediments. As a consequence of the ubiquity and importance of methane in major Earth events, Earth System models should include a comprehensive treatment of methane cycling but such a treatment has often been lacking. Here we implement methane cycling in the Danish Center for Earth System Science (DCESS) model, a simplified but well-tested Earth System Model of Intermediate Complexity. We use a generic methane input function that allows variation of input type, size, time scale and ocean-atmosphere partition. To be able to treat such massive inputs more correctly, we extend the model to deal with ocean suboxic/anoxic conditions and with radiative forcing and methane lifetimes appropriate for high atmospheric methane concentrations. With this new model version, we carried out an extensive set of simulations for methane inputs of various sizes, time scales and ocean-atmosphere partitions to probe model behaviour. We find that larger methane inputs over shorter time scales with more methane dissolving in the ocean lead to ever-increasing ocean anoxia with consequences for ocean life and global carbon cycling. Greater methane input directly to the atmosphere leads to more warming and, for example, greater carbon dioxide release from land soils. Analysis of synthetic sediment cores from the simulations provides guidelines for the interpretation of real sediment cores spanning the warming events. With this improved DCESS model version and paleo-reconstructions, we are now better armed to gauge the amounts, types, time scales and locations of methane injections driving specific, observed deep time, global warming events.

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